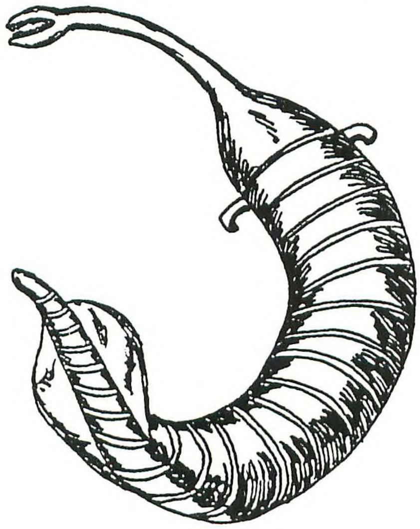
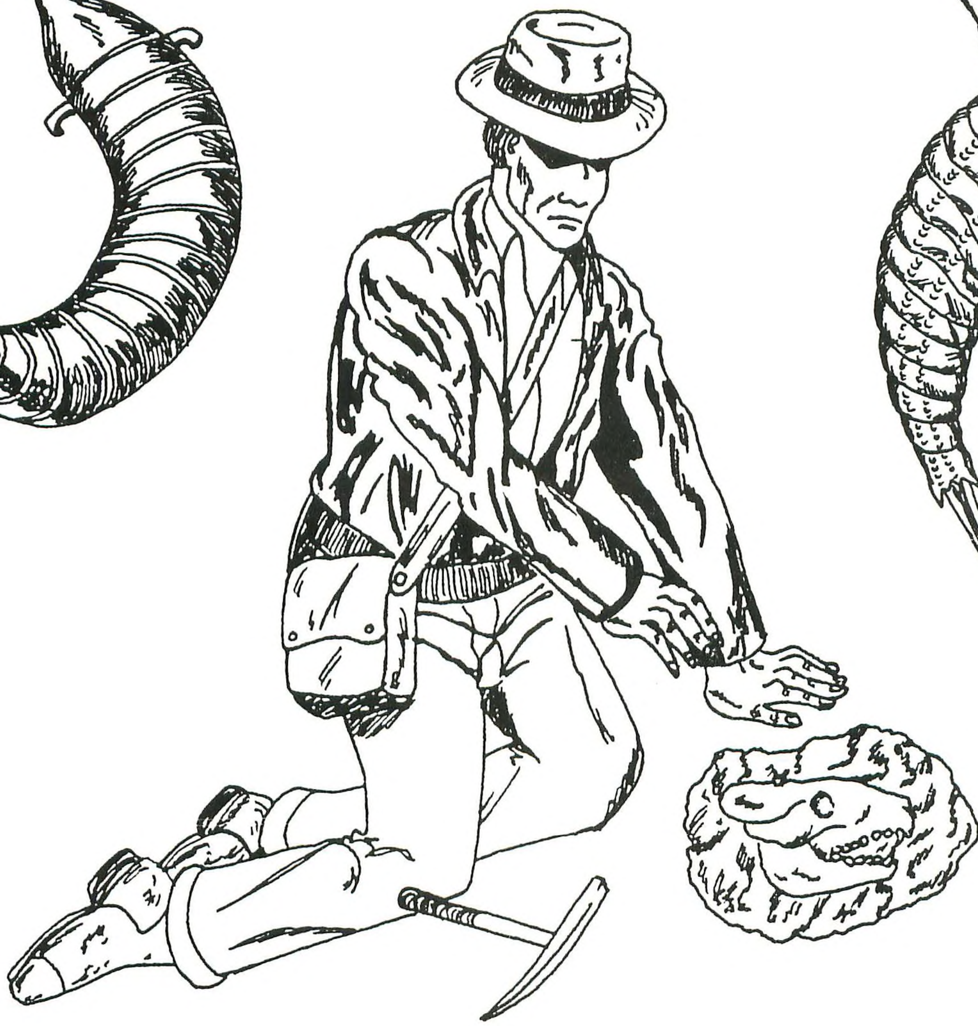
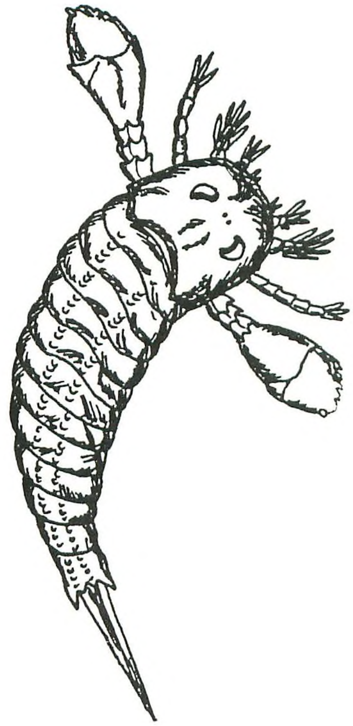
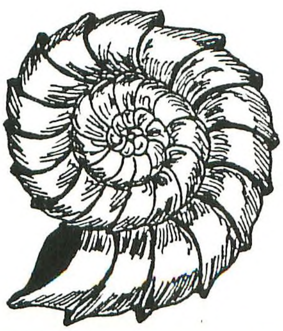
M·A·P·S Digest

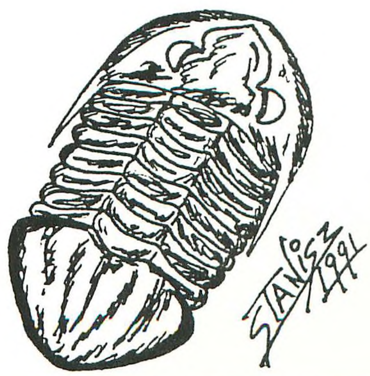
Official Publication of
Mid-America Paleontology Society











A LOVE OF FOSSILS BRINGS US TOGETHER

LAGERSTATTEN

(Extraordinary Preserved Fossil Faunas)

MAPS Digest

EXPO XIII EDITION

Mid - America Paleontology Society

A Love Of Fossils Brings Us Together

Western Illinois University
Union Ballroom
Macomb, Illinois 61465
April - 1991

ACKNOWLEDGEMENT

Among the many who have contributed to this EXPO XIII Edition. I should first mention **Dr. Desmond Collins**; for it was he who suggested the Theme, **"Lagerstatten"**, guiding me in a subject I was not too familar with; read about it of course but didn't give it much thought. "Lagerstatten, Extraordinary Preserved Fossil Fauna".

In my own mind all fossils which are preserved at all are extraordinary. They are the seeds of a knowledge to which we owe much in our lives today.

I suppose if there had been people here in America who could write and record what has been discovered on this earth when man was first here; we would have a much clearer picture of the stratigraphy of the earth. Imagine for a moment what extraordinary fossils have been exposed only to disappear from sight in ages past. It has only been within the last 200 years that man has developed knowledge of them; that is a very short time to define the records of a billion or more years.

I'm wandering away from the subject at hand, because I get so enthused over just the thought of finding a fantastic fossil to add to my collection.

Along with **Dr. Collins** I especially want to thank **Dr. N. Gary Lane**, for his help in securing names and addresses of people to get in touch with who are knowledgeable in the fossil fauna of historical sites.

MAPS members really came through with the articles. I have learned the people who are out there collecting are the ones who are most interested in the subject of **Fossils.** they are so eager to share their knowledge; and in so doing learn from their peers. If time comes when we ceased to learn something new, we will be as **old fossils.**

It is my pleasure to dedicate this issue, **EXPO XIII Edition**, to the **AUTHORS** and **ARTISTS**, for they are the ones who have shared with us their experitise, knowledge and enthusiasm. This is their Edition, please write them a note thanking them. They have my gratitude, they are appreciated.

The Mid - America Paleontology Society (MAPS) was formed to promote popular interest in the subject of paleontology, to encourage the proper collecting, study, preparation, and display of fossil material; and to assist other individuals, groups and institutions interested in the various aspects of paleontology. It is a non-profit society incorporated under the laws of the State of Iowa.

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COVER STORY

Raymond Stanisz
2508 Garfield Avenue
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The cover drawing was done by Raymond Stanisz, Jr. He is attending Indiana State University, where he is majoring in Graphic Arts. He has submitted art work of the proposed Indiana state fossil, Cyathocrinites multibrachiatus, which is now being considered for a final vote by the legislators this year. He has created super hero comic book characters, science fiction tee shirts and has worked on cartooning.

In the center of the cover we have a typical fossil hunter who has just uncovered a Merycoidodon skull (Oreodon) Class Mammalia, period Oligocene, a herbivorous animal of medium size. This specimen was found in the Badlands of South Dakota.

In the top left hand corner is a Tullimonstrum gregarium, period Pennsylvanian, commonly known as Tully Monster. Tullimonstrum gregarium is the state fossil of Illinois. It is only found in iron concretions of the Francis Creek Shale member of the Carbondale formation in Illinois.

In the top right hand corner is an Eurypterus remipes Dekay. the order Eurypterida in the phylum Arthropoda represents the largest forms of Chelicerates. All eurypterids are extinct and their fossilized remains are found in rocks of Ordovician to Permian age, with the largest variety of species found in Silurian rocks. Eurypterids are commonly called "sea-scorpions".

In the botton left hand corner is a Cathocrinites multibrachiatus. This species is found in the Mississippian age in Montgomery County, Crawfordsville, Indiana. The Crawfordsville fauna has been known to yield some of the world's finest crinoid specimens.

In the bottom center is an Ammonite Lytoceras immane Oppel, they are found in the late Jurassic period. They are mainly found in Europe. The ornamentation on the shell is not only beautiful but it also serves a purpose of strengthening the shell of the Lytoceras immane Oppel.

In the bottom right hand corner is an Isotelus which is the Ohio state fossil. It is found in rocks of the Ordovician age. The Isotelus reaches lengths of twenty inches or more.

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* Denotes MAPS Member

THE BURGESS SHALE FOSSIL LAGERSTÄTTE

by Desmond Collins
Royal Ontario Museum

Fossil Lagerstätten are defined as rock bodies unusually rich in palaeontological information, either quantitatively or qualitatively. The Burgess Shale Fossil Lagerstätte fits this definition to an exceptional degree by providing more information on more different kinds of animals than any other fauna in the Fossil Record.

The Burgess Shale is located in the Canadian Rocky Mountains on the west side of the ridge between Mt. Wapta and Mt. Field near the town of Field, British Columbia. Field is on the Trans Canada Highway, just west of the Alberta border. Both Field and the Burgess Shale are within Yoho National Park.

The Burgess Shale gets its name from the Burgess Pass trail that passes beneath it. It was discovered in 1910 by Charles D. Walcott, the Secretary of the Smithsonian Institution. Walcott first described the Burgess Shale in 1911, as part of the Stephen Formation. He excavated the Burgess Shale in the summers of 1910, 1911, 1912, 1913 and 1917, collecting over 65 000 specimens from the 7'7" thick layer that he called the Phyllopod bed. A second layer some 73 feet stratigraphically higher up yielded a few more specimens. Percy Raymond, from Harvard University, made a small collection from both levels (the upper excavation is now called Raymond's quarry) in 1930. A Geological Survey of Canada party led by Jim Aitken and Bill Fritz reopened both quarries in 1966 and 1967. Finally, in 1975, a Royal Ontario Museum party led by the writer picked over the talus left by the previous parties. Royal Ontario Museum parties have since spent 7 seasons in the Park successfully seeking new sites of fossils of the Burgess Shale type.

The two attributes that make the Burgess Shale fossils so important are their age, and their fine preservation. The Burgess Shale is dated from the Middle Cambrian epoch about 530 million years ago not long after animals first appeared on Earth. The preservation is so fine that many animal remains appear as lithographic "pictures" on the fine-grained, dark rock.

Walcott published short descriptions of the Burgess Shale fossils in 6 papers between 1911 and 1920. The first four, published in 1911 and 1912, described the fossils of soft-bodied or lightly skeletized

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Plate 1. Representatives of extant phyla in the Burgess Shale.

1. Sponge *Pirania* (Rigby, 1986).
2. Brachiopod *Micromitra* with setae (Walcott, 1912).
3. Coelenterate *Mackenzia*--a sea anemone (Walcott, 1911).
4. Mollusc *Hyolithes* (Yochelson, 1961).
5. Echinoderm *Echmatocrinus*--a crinoid (Sprinkle, 1976).
6. Priapulid *Ottoia* (Gould, 1989).
7. Annelid *Canadia* (Gould, 1989).
8. Chordate *Pikaia* (Gould, 1989).

animals--what Walcott identified as jellyfish, sea-cucumbers, annelid worms and arthropods. Fossils of soft-bodied animals are extremely rare, so the publication of the descriptions and illustrations of such remains from so far back in time caused a sensation. For many animal groups, the fossils described were the earliest known representatives by far, and in some examples, they were the only fossil representatives known. Walcott collected many more specimens after the publications of 1911 and 1912, and said that he intended to publish more detailed descriptions, but except for descriptions of four trilobitelike arthropods and additional photographs of other species published posthumously in 1931, none were. It was to be another 60 years before detailed descriptions began to appear.

The detailed descriptions came from the restudy begun with the new excavations of the Burgess Shale by the Geological Survey of Canada in 1966 and 1967. The research was carried out principally by Professor Harry Whittington of Cambridge University, assisted by four Cam bridge students: Derek Briggs, Simon Conway Morris, David Bruton and Chris Hughes. Between 1971 and 1985 these scientists published more than 25 papers describing most of the soft-bodied Burgess Shale fossils. To their surprise, they were unable to place many of these Cambrian animals within a known class or even a known phylum, as Walcott had done.

Stephen Jay Gould in his 1989 best-selling book, "Wonderful Life. The Burgess Shale and the Nature of History", has taken the threads of these reinterpretations of the Burgess Shale fossils and woven a startling theory. First, Gould looked at the arthropods. Of the 20-odd Burgess Shale arthropod genera described, 5 or 6 can be classified in known classes, but 15 cannot. This suggested to Gould that most Cambrian arthropod classes, based on the genera that cannot be classified, are now extinct. Next, Gould looked at the other soft-bodied Burgess Shale animals. Eight (8) cannot be classified in animal phyla living today. Gould considered that these 8 "weird wonders" could represent 8 different Cambrian phyla that are now extinct. From these two lines of evidence, Gould concluded that more than half of the major animal groups (phyla) present in Cambrian seas are extinct. He attributed this to the effects of Contingency (= Mass Extinction), which were much greater than previously realized. Indeed, says Gould, humans are lucky to be alive!! If *Pikaia*, the nearest human ancestor so far recognized in the Burgess Shale, had not survived the Contingency events, there would have been no descendants to lead to us.

Plate 2. Burgess Shale arthropods. All drawings are from Gould, 1989, except for #'s 1 and 3.

1. Trilobite *Olenoides* with appendages (Whittington, 1975).
2. Crustacean *Canadaspis*
3. Chelicerate *Sanctacaris* (Briggs & Collins, 1988).
4. Uniramian *Aysheaia*
5. Unclassifiable *Leanchoilia*
6. Unclassifiable *Odaraia*
7. Unclassifiable *Yohoia*
8. Unclassifiable *Marrella*

The saga of the Burgess Shale continues. On the one hand, new "weird wonders" have been discovered in new Burgess Shale lithographic fossil sites excavated by the Royal Ontario Museum parties, and in Lower Cambrian lithographic fossil sites found in China and Greenland. Such forms increase the known amount of animal Disparity in Cambrian life and so increase the effects of Contingency. On the other hand, renewed attention to Gould's eight "weird wonders" has already produced evidence that one, *Wiwaxia*, is an annelid worm, and doubts about the unclassifiability of some of the others. Such interpretations will reduce the known amount of animal Disparity in Cambrian life and so decrease the apparent effects of Contingency.

Whatever the outcome of these conflicting trends in interpretation of Burgess Shale fossils, it is evident that the Burgess Shale is uniquely "unusually rich in paleontological information" and is our most important Fossil Lagerstätte.

Acknowledgements

The drawings were done by Marianne Collins of the Royal Ontario Museum. The ones from "Wonderful Life" are reprinted with permission from Stephen Jay Gould.

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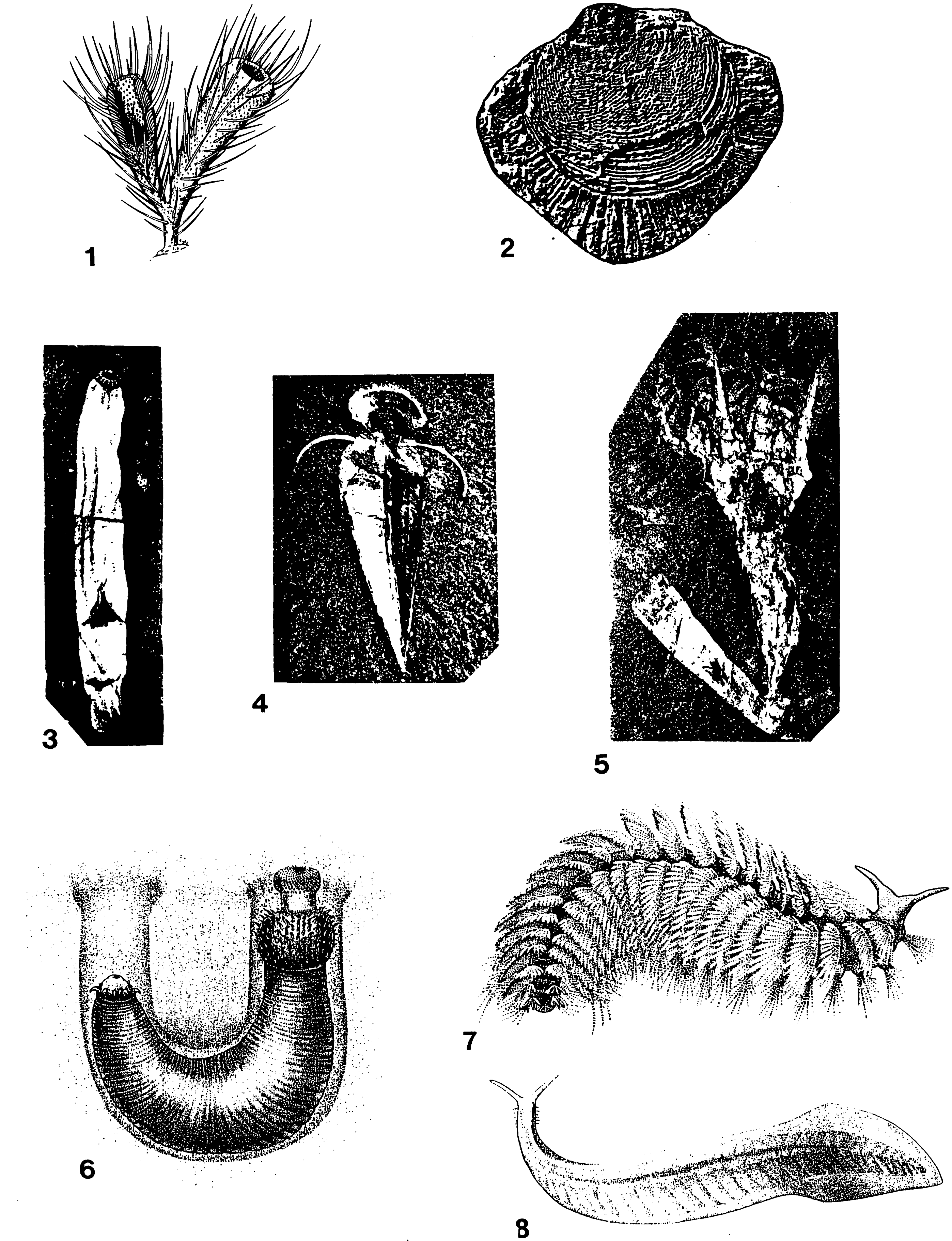
Plate 3. Burgess Shale "weird wonders". All drawings are from Gould, 1989.

1. *Amiskwia* 2. *Odontogriphus*
3. *Wiwaxia* 4. *Dinomischus*
5. *Hallucigenia* 6. *Nectocaris*
7. *Opabinia* 8. *Anomalocaris*



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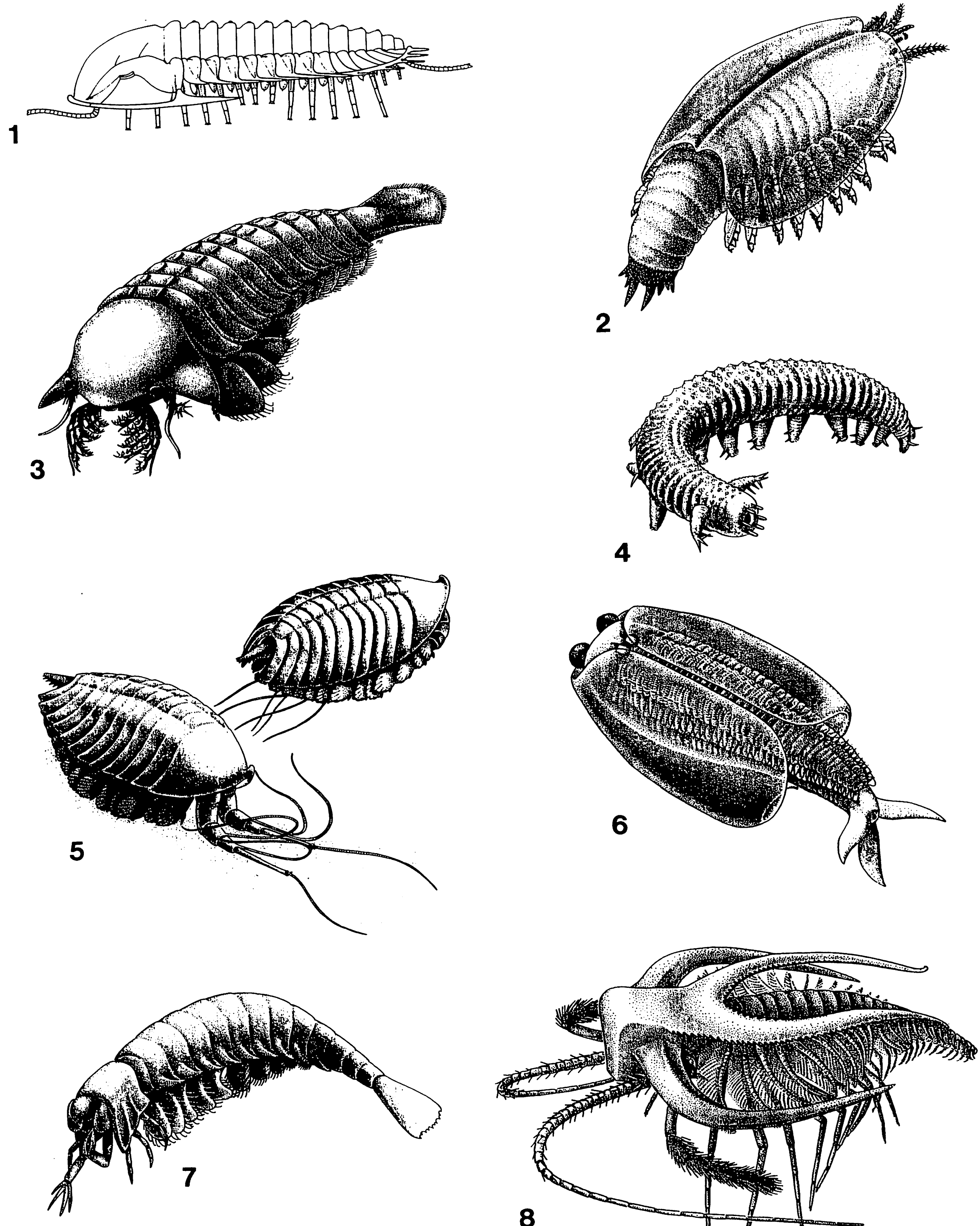

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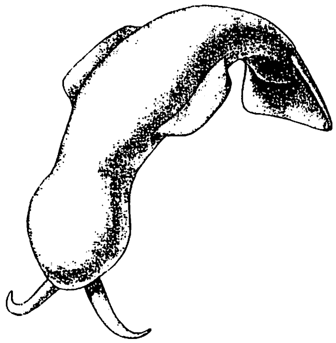
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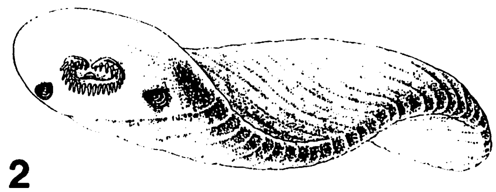
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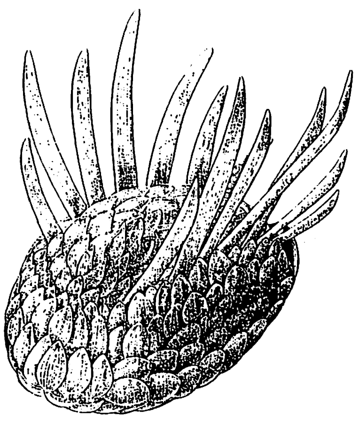
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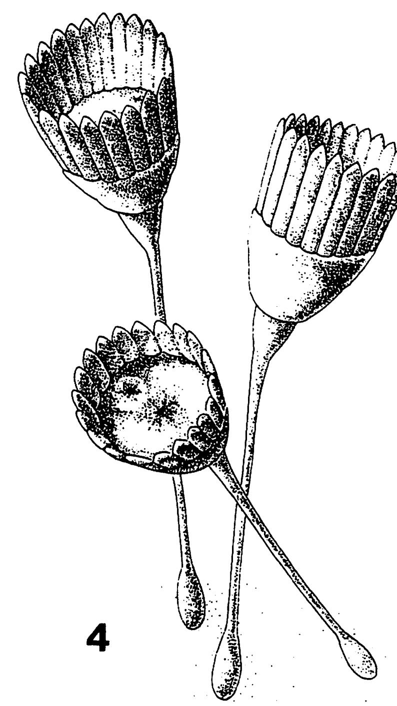
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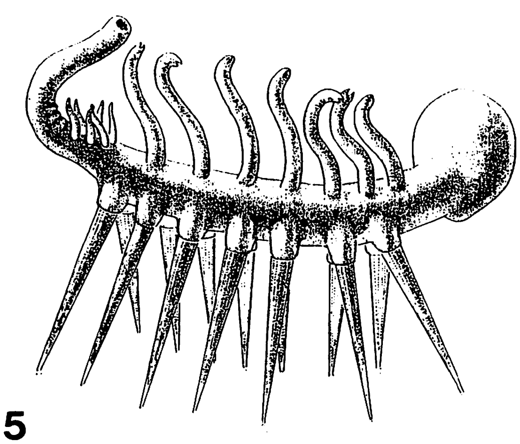
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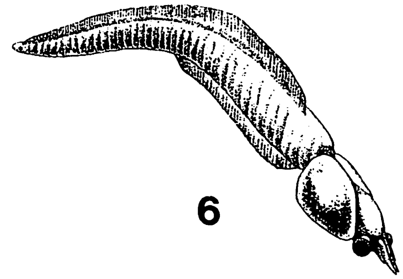
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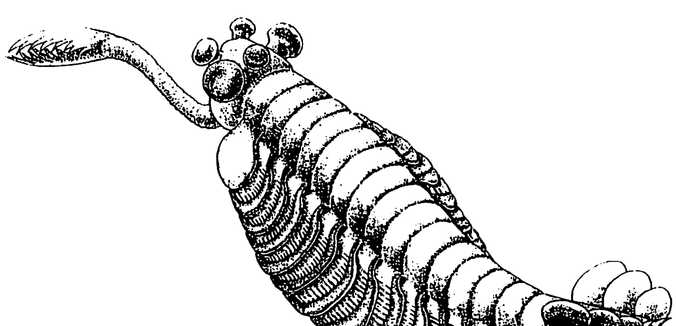
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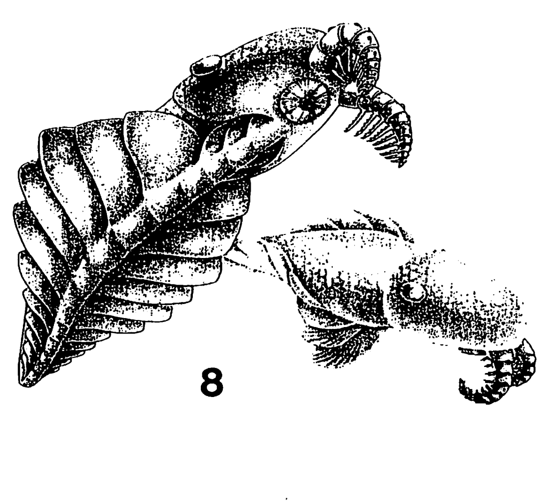
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Plate 3

A SCENE FROM MIDDLE CAMBRIAN SEAS

The largest known predator from the Cambrian, *Anomalocaris nathorsti* (with long spines on its claws), rears up following a miscalculated attack on a fleeing trilobite. At the same time, *Anomalocaris canadensis* (with short spines on its claws) grasps another trilobite on the sea floor.

Large numbers of trilobites, including a few with bite marks, and *Anomalocaris canadensis* claws occur in the famous trilobite beds on Mt. Stephen, just across the Kicking Horse Valley from the main Burgess Shale site on the ridge between Mt. Wapta and Mt. Field, British Columbia.

Drawing by Marianne Collins, Royal Ontario Museum.

FOSSILS OF THE MIDDLE DEVONIAN

SILICA FORMATION

A RICH TREASURE TROVE OF FANTASTIC FOSSIL

HUNTING IN THE 60'S AND 70'S

Thomas C. Witherspoon
6611 Miller Road
Dearborn, MI 48126

The Silica formation was deposited over 350 million years ago and the fossils that lived in those Middle Devonian Seas were buried by sediments that not only preserved them for us to see and appreciate but literally made us willing to spend countless hours collecting them.

The world famous trilobites Phacops rana crasituberculata and the elusive Phacops rana milleri were the main reason that paleontologists and amateurs alike had to make the trek to the Medusa Quarries. We not only collected those magnificent trilobite creatures preserved in calcium carbonate and pyrite but also the other beautifully preserved brachiopods, crinoids, corals, bryozoans and many other genera that lived in those seas.

The inspiration, fascination and obsession to collect those Silica fossils was immediately sensed by the author when others came to see and admire his fossils. The artistic beauty that was displayed by the fossils themselves was enough to completely captivate a person. They were the inspiration that brought thousands to visit the Medusa Quarries in northwestern Ohio every year. They were the reason people would literally crawl over the dumping slopes on their hands and knees all day over a muddy slope, looking for those elusive fossils. There was always the thrill of discovery and the joy of anticipating what you might uncover. The next fossil you found might be a member of an undiscovered species.

Only after many days in the field and long and thorough collecting from any locality, does the hunter begin to realize each layer or bed has its own assortment of fossils. It is always hard to believe that the Silica Formation creatures which secreted them have been dead for 350 million years.

Several of the units of the Silica Formation are thick shale beds. These represent a slow uninterrupted accumulation of material over a span of time. In 1970 Dr. Robert Kesling (in Ehlers and Kesling, pp.33-39) called this a diverse fauna zone, characterized by deep mud flats which represent the final seaward transport of clay particles. The claystone, or shale, has generally a very low calcareous content and may reach exceptional thickness without intervening beds. Because of this slow build up, we may conclude that the region of the quarries was fairly far removed from the nearest shore of the Middle Devonian Sea, when the Silica Formation was laid down.

Another interesting theory is Dr. Robert Kesling's statement "inasmuch as corals, which today need light for their existance, are present in the limy parts of the Silica Formation, we may judge that the deepest water covering the area during the period of deposition was probably not much over 150 feet."

In the good old days back in the 60's a steady stream of cars from all over the United States and Canada headed for Silica, Ohio, where the Medusa Cement Quarries were lacated. By the early 60's the south Medusa Quarry was no longer in operation and it was beginning to fill with water. The north quarry was going full blast. Most of the hunters tried to arrive at the quarry office for their permission sheets just after the last shift had finished for the weekend.

Most of these intrepid collectors, amateur paleontologists if you will, were after the "black bugs" or trilobites which could be rolled or flat. The majority were rolled up (as a pill bug does today) and it was a very lucky person who managed to capture a whole flat one. It surely was fun to hunt the dump piles of Unit 9 shale which had been discarded by the quarry personnel. Equally exciting was to look for crackes on the botton of Unit 9 and the top of Unit 8. This was where you could find the large "crassies" trying to hide under blankets of shale from the eyes of the fossil hunters.

Those invertebrates, the extinct trilobites, evolved towards outer armor as typified by the living crayfish, lobster or crab, the body and even the joints of the legs are encased in an armor, with complicated internal muscles to operate them; similarly, the extinct trilobites and other arthropods of the Devonian had an external skeleton of chitin and calcium carbonate that was secreted by the animal. (This chitin is similar to the material in one's fingernail). The arthropods at each stage of growth were prisoners in an outside coat of armor; they could grow only by molting, casting off the hard covering to grow rapidly before secreting another and larger suit. The molting process left behind the old skeletons, so that one trilobite could in its lifetime produce several "fossils" in the sediment. Complete extended ones, and the enrolled ones, represent trilobites that have died.

"Trilobites appear to have filled the roll of scavengers on the Silica Formation sea floor, probably also ingesting quantities of organic-rich mud. No evidence has been uncovered to suggest that the Phacops trilobite was ever an active predator."

Other sought after fossils were the generally large articulate brachiopods the Paraspirifer bownockeri, Brachyspirifer audaculus and the Spinocyrtia "eurytheines" which had been pyritized and finely coated with calcium carbonate. They were extremely beautiful and if you were lucky to hit a pocket of them, you might find a hundred or more. More often you were lucky to find a few good ones in the shale.

A good example of the beauty of the Silica Formation trilobites, crinoids and brachiopods can be seen in the following plates of some of the fossils in the Kesling and Chilman book Strata and Megafossils of the Middle Devonian Silica Formation by Robert V. Kesling and Ruth B. Chilman. This book was published in 1975 by the Friends of the University of Michigan Museum of Paleontology, Inc., and is now out of print.

A new quarry has been opened in the Silica shale formation at the old Medusa Cement properties. For more information on hunting in this new quarry and fees, please contact - - - Ray Meyer at 1-(419) 843-2314 or write him at 2557 Moffit Street, Toledo, Ohio 43615.

EXPLANATION OF PLATE 12

All figures x $1\frac{1}{2}$

Brachiopods

FIGS. 1-8 -- Mediospirifer audaculus (Conrad), unit 7, 8, or 9, Medusa quarries. 1-3, UMMP 61042D, dorsal, posterior, and anterior views of "typical" specimen. 4, 5, UMMP 61042C, dorsal and posterior views. 6, UMMP 61042B, interior of brachial valve. 7, 8, UMMP 61042A, dorsal and ventral views of young specimen. The generic assignment of this large brachiopod has been much debated by brachiopod experts. Here we place it in Mediospirifer.

FIGS. 9-16 -- Rhipidomella vanuxemi Hall, unit 7, Medusa quarries. 9-12, UMMP 61157C, 61157B, 61157A, and 61082D, interiors of four pedicle valves. 13, 14, UMMP 61082B, ventral and lateral views of good specimen. 15, 16, UMMP 61082C, ventral and dorsal views. "Rhip van" is typical of unit 7, although it is also recorded from unit 15.

FIGS. 17-20 -- Rhipidomella cf. penelope (Hall), unit 7, Medusa quarries. 17, 18, UMMP 61080B, ventral and posterior views of young specimen. 19, 20, UMMP 61080A, ventral and dorsal views of mature specimen. The short hinge line is characteristic of Rhipidomella, as are the fine ridging and growth lines.

PLATE 12

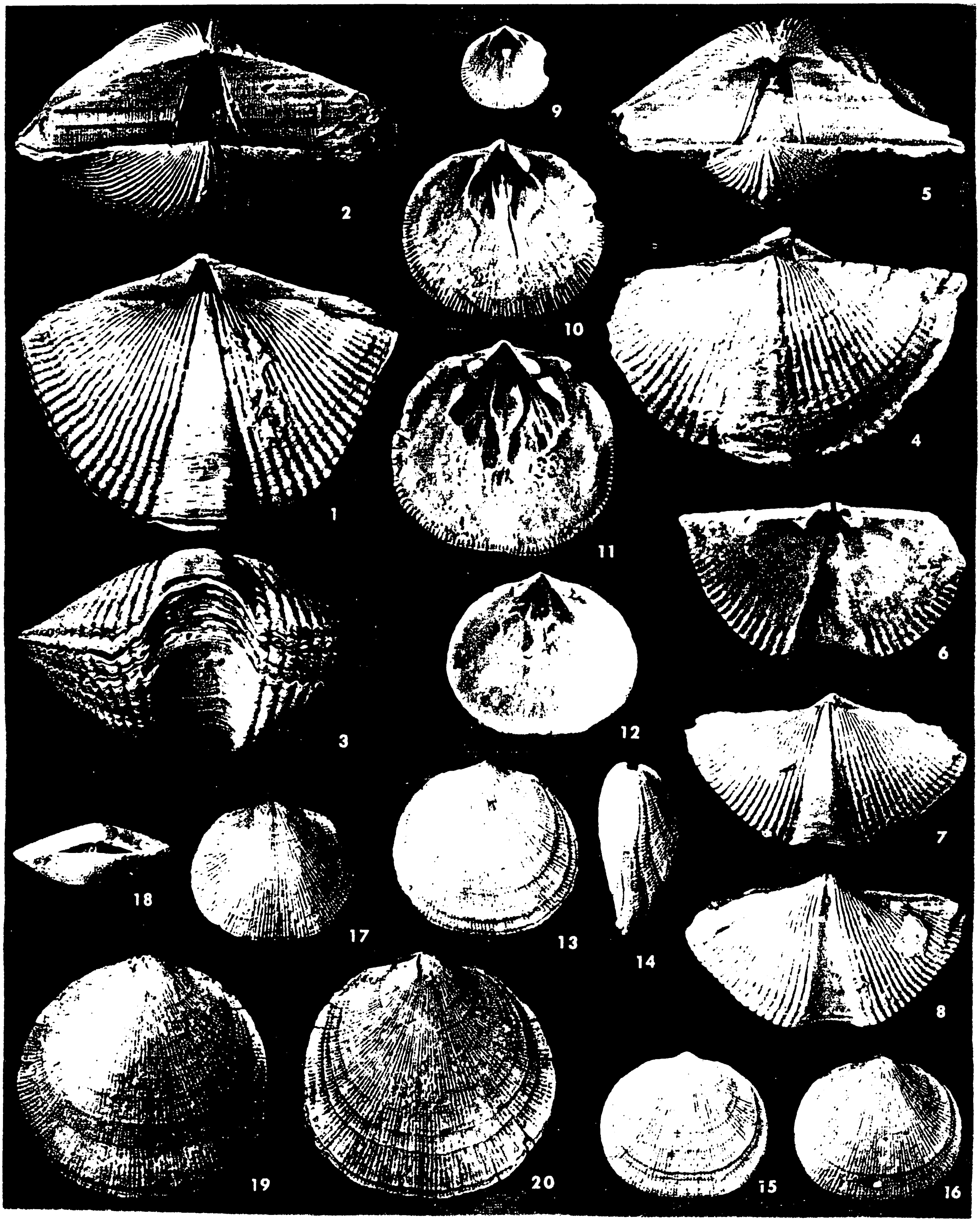


PLATE 22

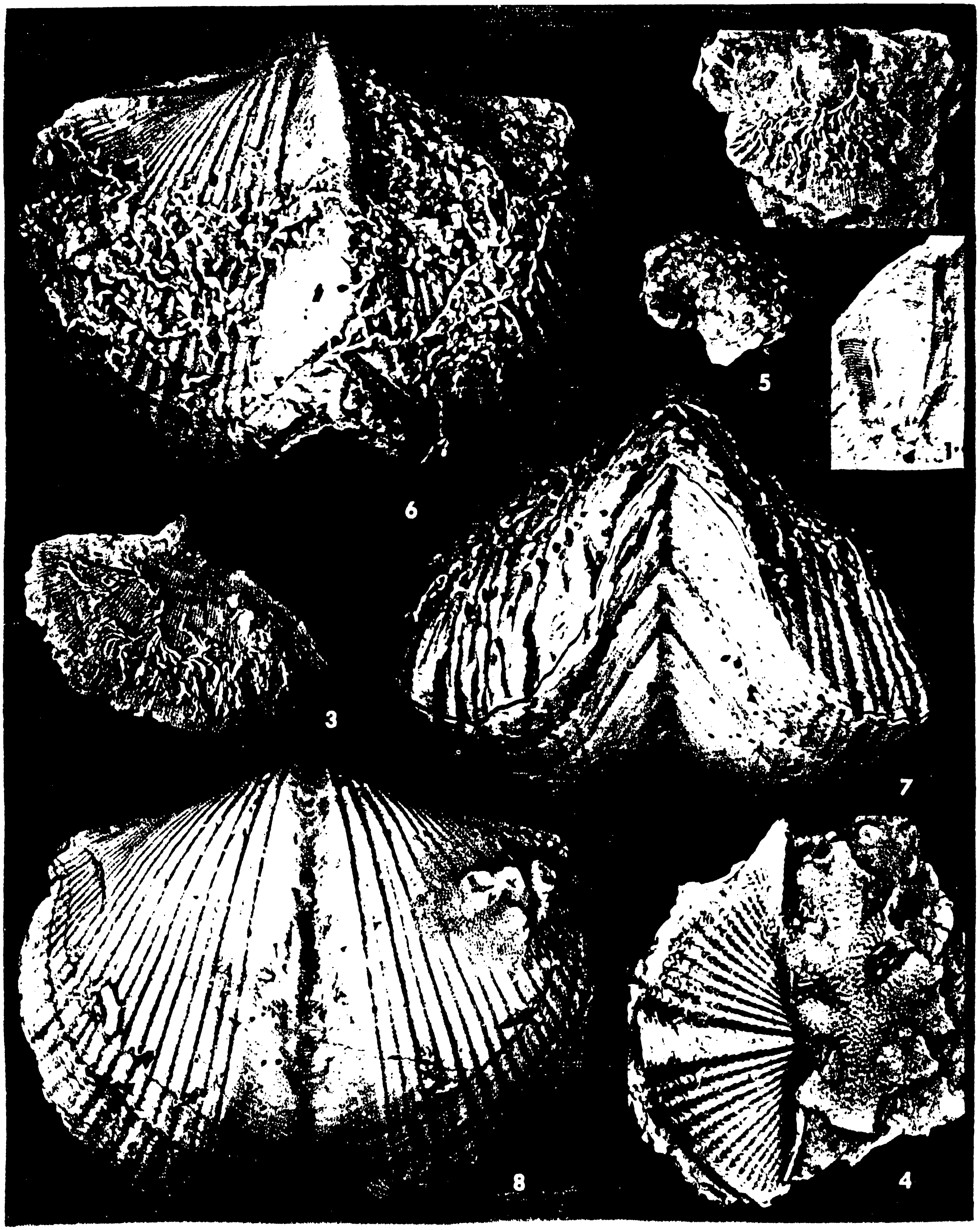


PLATE 24

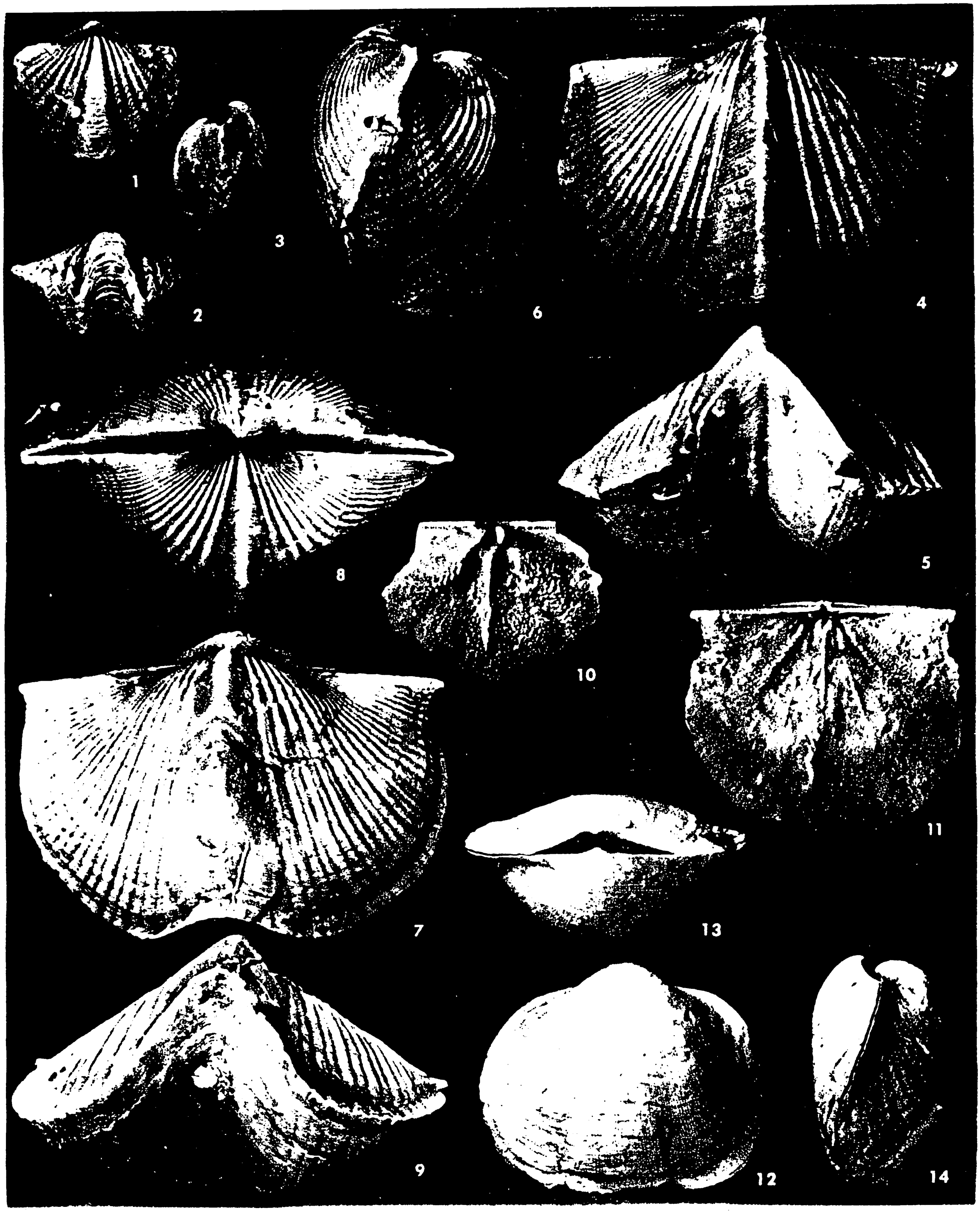


PLATE 33

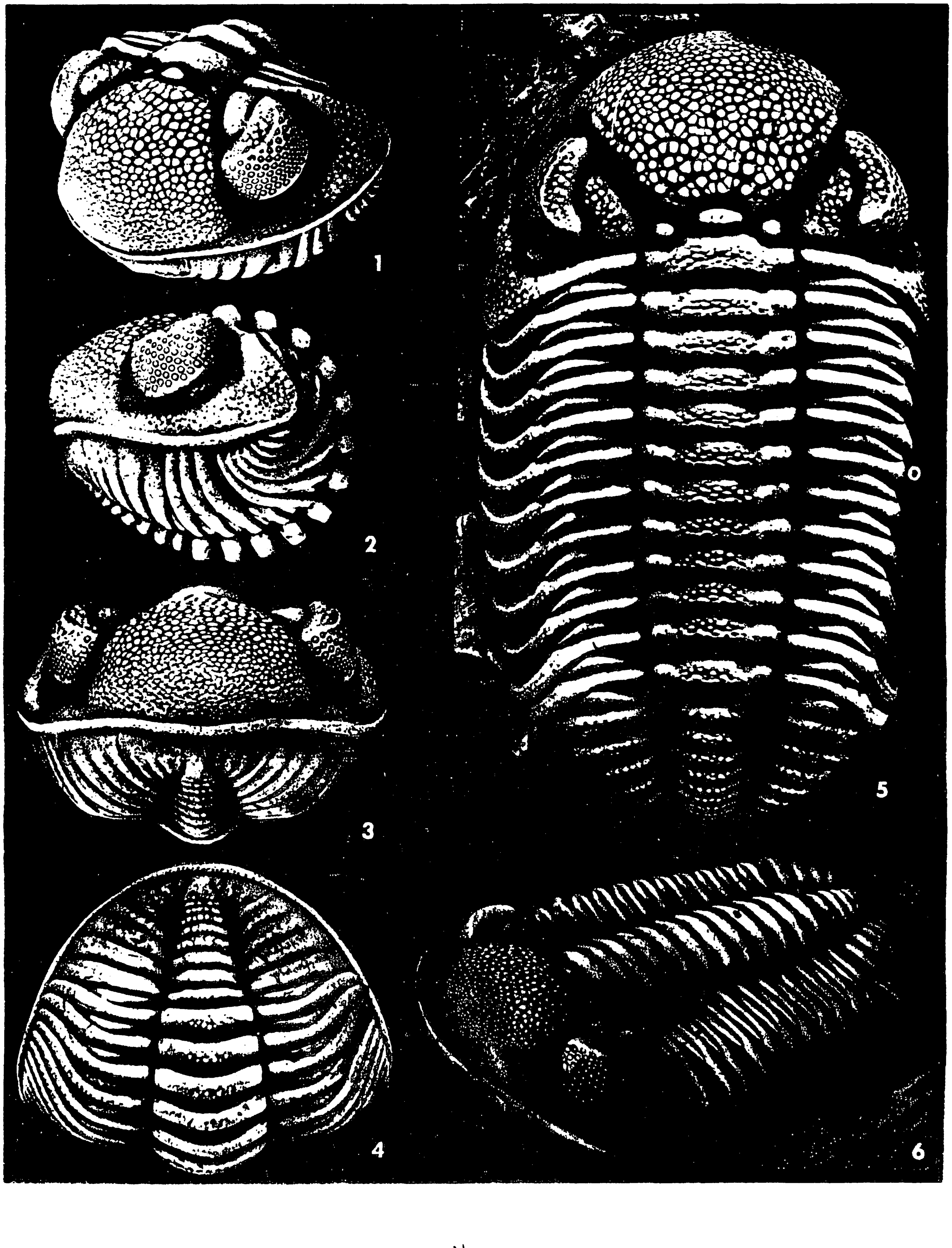
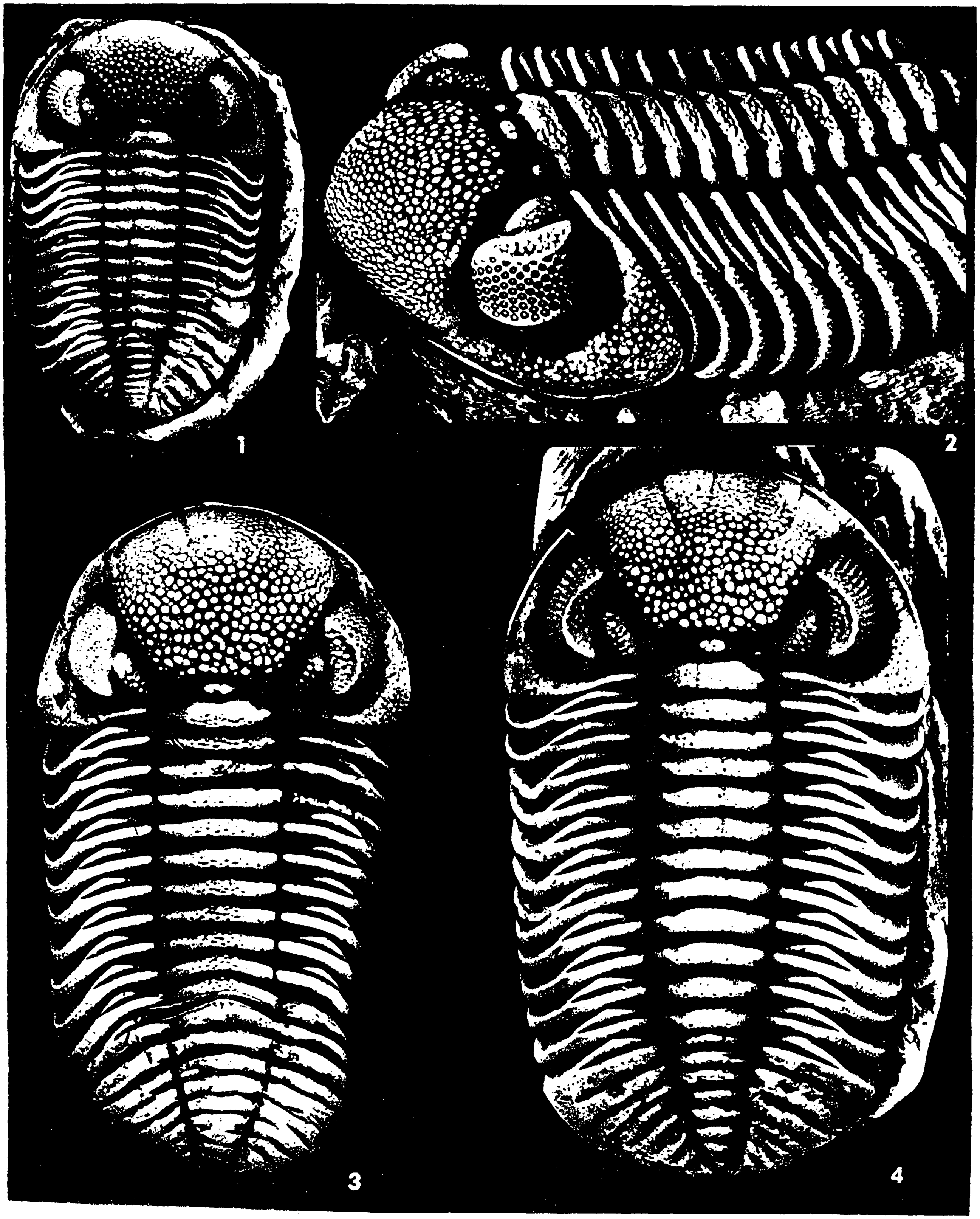


PLATE 34



EXPLANATION OF PLATE 22

All figures x 2

FIG. 1 -- Conularia sp., UMMP 61274; unit 18A, Medusa North Quarry.

FIGS. 2, 3 -- Hederella cf. thedfordensis Bassler, UMMP 61146; two specimens showing the pattern of colonial development.

FIG. 4 -- Sulcoretepora deissi McNair, UMMP 61182; unit 7, Medusa North Quarry; collected by Ruth Chilman. Excellent specimen on slab of unit 7, showing branching habit and lunaria.

FIG. 5 -- Platyceras rarispinum Hall, UMMP 61312; Martin-Marietta Quarry; collected by Ruth Chilman. This young individual was still producing spines at the edge of its shell.

FIGS. 6-8 -- Paraspirifer bownockeri Stewart, UMMP 61129; specimen found in dumped material at Silica by Larry Magrum, probably from unit 9, Medusa North Quarry. This individual was attacked at various times by occasional sponges during its youth, leaving the borings seen on the posterior areas of the two valves. Then in early maturity it suffered an infestation of boring sponges which left a line of holes along the mantle edges of the valves. Not long thereafter, the left side of the brachial valve was beset with some damaging organism, probably Cornulites, which completely distorted the pattern of costae and grooves in the adult portion of the shell. On the right corner of the pedicle valve (fig. 8) is a patch of Atactotoechus reticulatus (Hall), a thinly encrusting bryozoan. The brachial valve (fig. 6) was settled by colonies of Hederella.

EXPLANATION OF PLATE 24

Figures x $1\frac{1}{2}$

Brachiopods

FIGS. 1-3 -- Mucrospirifer profundus (Grabau), unit 7, Martin-Marietta Quarry. UMMP 61275, dorsal, anterior, and lateral views of complete specimen.

FIGS. 4-9 -- Paraspirifer bownockeri (Stewart), unit 9, Medusa quarries. 4-6, UMMP 61066, dorsal, anterior, and lateral views of well-preserved specimen with good ornamentation. A few scars of a late infestation of Cornulites along the margin. 7-9, UMMP 61067, dorsal, posterior, and anterior views of excellent specimen preserving the small mucronate tips at the corners; no Cornulites have marred the borders, but a few sponges have bored into the shell material.

FIGS. 10, 11 -- Protoleptostrophia perplana (Conrad), unit 7, Medusa quarries. 10, UMMP 61078D, interior view of incomplete brachial valve, showing the hingement and muscle scars. 11, UMMP 61078C, interior view of nearly complete pedicle valve, showing the hingement and muscle scars of a fairly small specimen. A large specimen is shown in plate 13, figures 2 and 3.

FIGS. 12-14 -- Schizophoria ferronensis Imbrie, Martin-Marietta Quarry. UMMP 61026, dorsal, posterior, and lateral views of a mature specimen, showing the short hinge and the subdued ornamentation.

EXPLANATION OF PLATE 33

All figures x 2

Trilobites

FIGS. 1-5 -- Phacops rana crassituberculata Stumm. 1-4, inclined, side, front, and bottom views of an enrolled specimen from the collection of the Chilmans. 5, top view of an extended specimen, also from the Chilman's collection. In this subspecies, the glabella has coarse tubercles; smaller tubercles are present on the genal area (corner of the head) and on the areas above the eyes. Distinct tubercles are present along the axial lobe, both on the thorax and on the pygidium (tail). "Crassi" has an average of 84 facets on each eye; each facet is bordered by a nearly polygonal rim and its center does not extend beyond the general level of the eye surface. The fairly large facets are arranged in diagonal rows. Figure 5 shows the narrow zones of tuberculation on the lappets of the pleural lobes.

FIG. 6 -- Phacops rana milleri Stewart, inclined view of an extended specimen from the collection of the Chilmans. As compared with subspecies "crassi" above, this subspecies has smaller tubercles on the glabella and elsewhere is smooth or provided with muted ornamentation. Each eye in milleri has an average of 104 facets arranged in about 18 vertical rows; each facet is small but strongly convex, extending outward beyond the general level of the eye.

Phacops rana crassituberculata is usually found in units 7 and 8, whereas Phacops rana milleri is usually found in units 8 and 9. Occasionally, both species are found on the same slab, proving that for a while they were contemporaries.

EXPLANATION OF PLATE 34

All figures x 2

Trilobites

FIGS. 1, 4 -- Phacops rana milleri Stewart, specimens from the collection of the Chilmans. Top views of a small and a large specimen. In these views, the facets appear to be arranged in vertical rows, with approximately 18 rows in each eye. The average number of facets in this subspecies is 104, the highest number for any Phacops. The free cheeks are nearly smooth, and the axial lobe of the thorax has very faint ornamentation. Each eye facet is nearly circular, and clearly convex, extending outward beyond the general level of the eye.

FIGS. 2, 3 -- Phacops rana crassituberculata Stumm, specimens from the collection of the Chilmans. Inclined and top views of extended specimens. The eye facets alternate in the vertical rows, so that they appear to be disposed diagonally. Each facet is bordered by a polygonal rim, and is not nearly so convex as those of milleri. The average number of facets per eye in this subspecies is only 84. The glabella has coarser tubercles than does milleri, and the free cheeks are provided with smaller tubercles and pits, in which it is presumed the animal bore sensory hairs. The axial lobe of the thorax is coarsely tuberculate, and even the edges of the pleural lobe segments have distinct tubercles.

Both subspecies can occasionally be found on the same slab, so that they were actually in competition at one time. Usually, however, Phacops rana crassituberculata occurs in units 7 and 8, whereas Phacops rana milleri occurs in units 8 and 9.

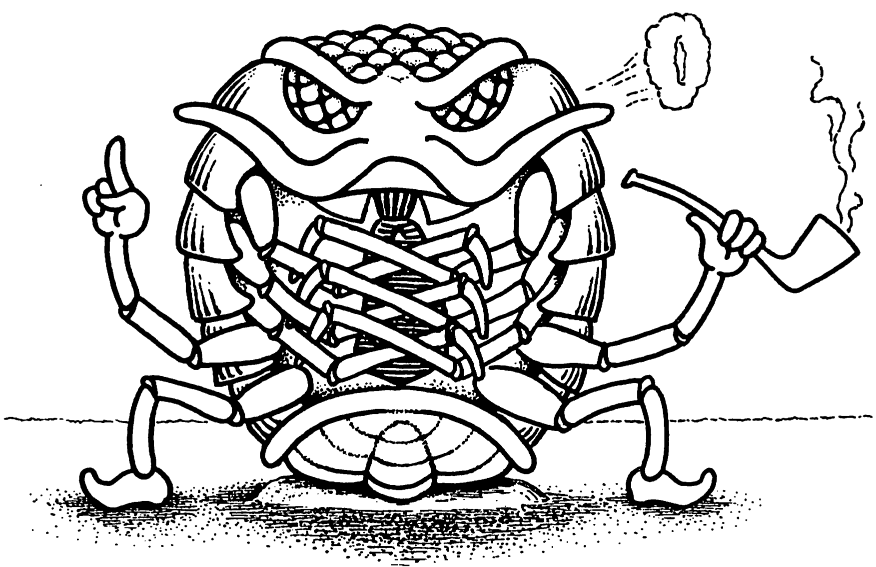
Interrogating the Fossilized Witness

Robert V. Kesling

TO ACHIEVE HIS GOAL of reconstructing conditions of the past, the paleontologist must extract as much information as possible from his fossils. To get the desired answers, we must ask the right questions. Many items could be investigated, but ten stand out in my view. Of these, some could be studied in museum specimens, some can only be determined in the field exposures, and some can be looked at in other collections and publications. The following are some items and questions that you may find useful in paleoecology.

The Museum Specimen

Most studies of fossils are centered on the collections of a museum, for there are assembled the treasures of years of field effort. For certain formations, paleontologists say, "The best collecting ground is the --- Museum" and this is often true, for some exposures that once yielded excellent specimens no longer exist -- covered over by slump, cemented over by man's constructions, or removed by erosion. So the museum collections may in some cases by the only source of information on the past. Bear in mind, please, that the individual fossil actually once experienced the conditions of temperature, sea depth, currents, sediment accumulation, turbulence, and bottom geography which you would like to reconstruct by inference.



It usually takes a little research to get your fossil in a confessing mood ...

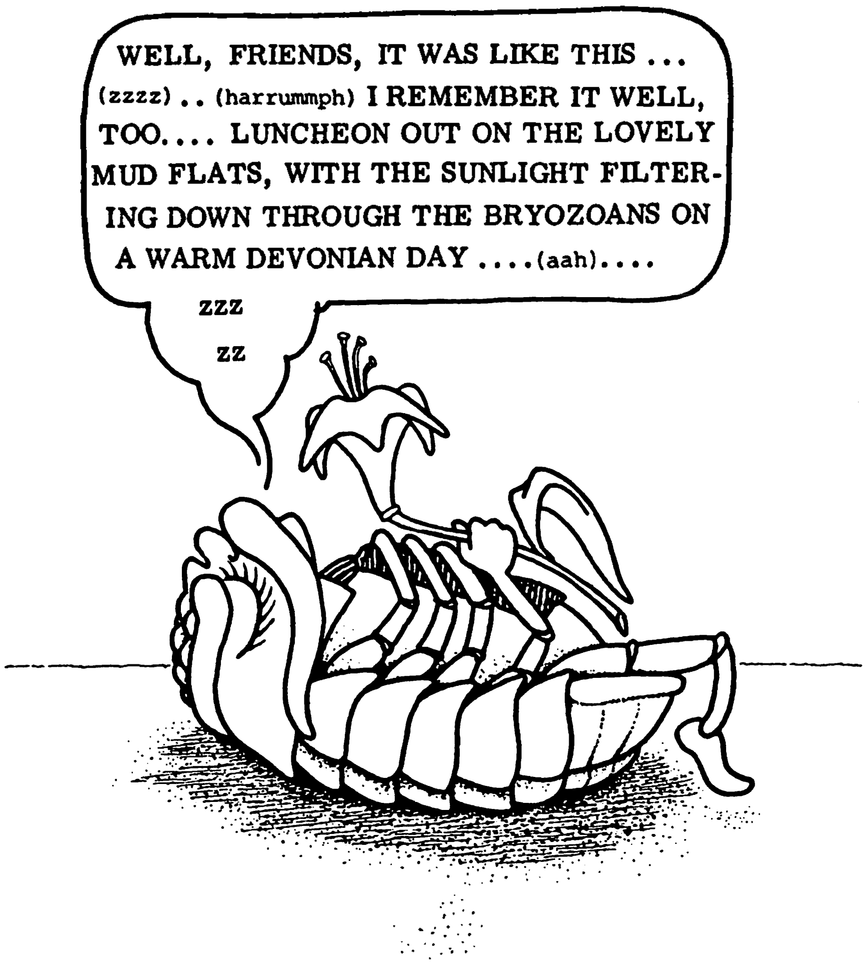
Item 1. Identity. What it is.

To what phylum, class, family, genus, and species does it belong?

Whatever we can learn about a fossil, we must know what it is. If we can only identify it as a member of the Class Trilobita, then anything we can decipher can only be applied to trilobites in general.

Is it new? If so, what are its nearest relatives like?

If your fossil proves to be new, then it can only be compared with its closest relatives



Even though he has been dead for 350 million years, your fossil can still tell a story if you insist ...

for purposes of interpretation. On the other hand, it becomes very important to get as much information as possible from the only known specimen of a new species.

How did this or similar animals live?

Classification is significant because it can put you on the track of how the animal made its living. Knowing what the specimen is will permit you to plug into all that other paleontologists have been able to discover about this kind of animal. If it is a coral, we know that it was permanently fixed in place during practically all of its life; and if we know it is a tabulate coral, then we know also that it branched out to form a colony. If your fossil is a crinoid, it fed upon microscopic organisms borne by the currents. Or if your fossil is a trilobite or fish, it was mobile and could move about to search for its food.

Item 2. Population of its species. What sizes and ages are represented.

Unfortunately, the museum collection may not be thoroughly reliable on this item. Collectors pick out the largest, best preserved of the fossils available in the field -- unless, of course, they know better.

Is the preserved population of this species balanced, like it must have been in life?

If individuals of all ages are represented, then the whole population must have been snuffed out at once, preserving the "balanced" distribution. If there was no catastrophe, then the final population will be of the individuals that died of various causes, mostly old ones that succumbed to the debilities of advanced age along with a few younger individuals that met untimely death.

Are there young specimens as well as old?

If there are abundant young individuals in the population of the dead, we would like to find out why they died.

Item 3. Community structure. What were the contemporaries of your fossil at that place.

Where does your specimen fit in the power pyramid of the fauna?

The community is of as much interest as the population of your species. In the power pyramid, we would expect the dominant forms to be relatively scarce, as compared to their prey. Even scavengers had their limitations, depending upon the rate at which other animals died in the environment.

Are there any preserved fossils that could have been food for your species?

For many of the filter-feeders, the microscopic particles upon which they fed may no longer be identifiable. But for the voracious meat-eaters, a supply of prey was probably also capable of preservation.

What may have preyed upon your species?

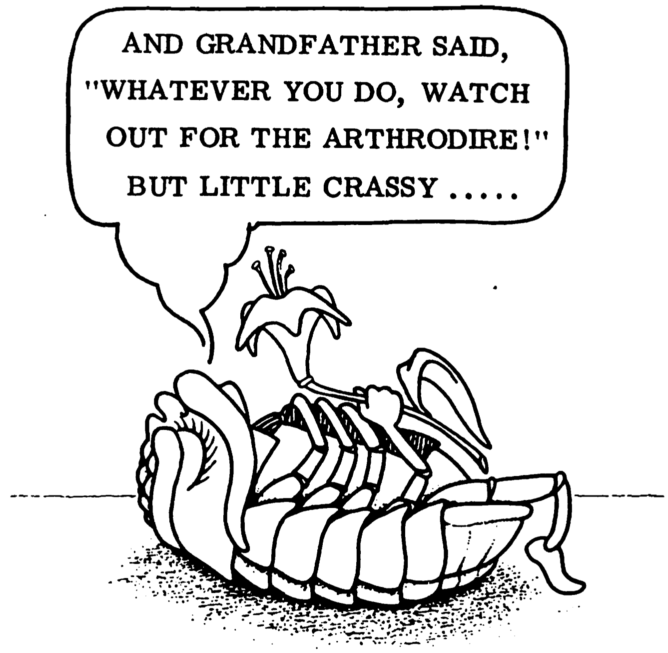
In the food cycle, your species may have been preyed upon by other organisms. Look for any marks or indications of "narrow escapes" by your fossil.

In the process of trying to determine just how many there were of each kind of animal in the community, we must pay attention to the biology of each species. In ontogeny, for example, one trilobite can leave behind several incomplete "skeletons" by molting -- one for each of the sizes he passed through. But a bivalve will have only one fossilized "skeleton" -- the one to which he added little increments along the edge as he needed more cover. The crinoid produced only one cup, but its stem could disarticulate into numerous columnals. Taking the census in the Middle Devonian mortuary is not always as easy as it might appear.

Item 4. Preservation. What is the fossil made of now, as compared with its composition during life.

Was the specimen drastically altered before burial?

Some of the Silica specimens, like the cephalopods, seem to have been dissolved very soon after death, long before they were deeply buried. If we assume that, like the living chambered Nautilus, they were composed of aragon-



... and keep on telling about the "good old Middle Devonian days" ....

ite, then we can explain why they were more soluble than the molluscs which secreted calcite in their shells.

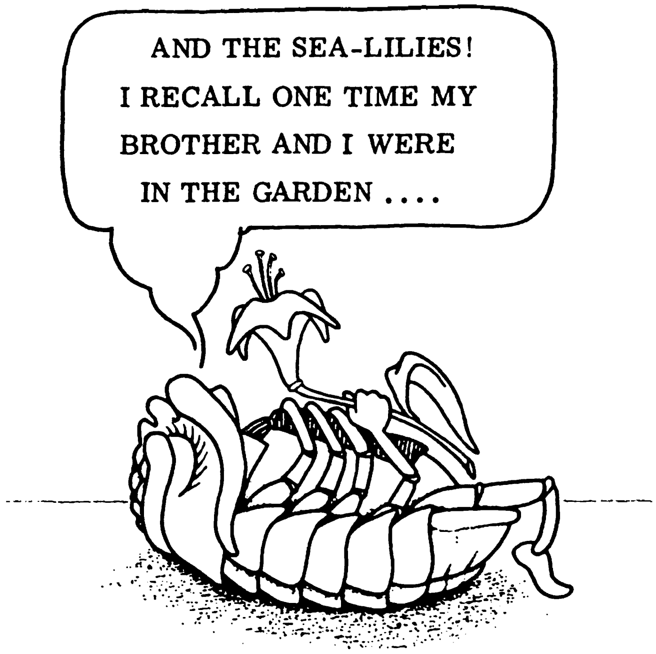
Was the specimen replaced by pyrite or silica?

All our evidence points to early replacement by pyrite, if the conditions of pH and Fe are suitable. The brachiopod Paraspirifer is nearly always replaced by pyrite, and the specimens are excellently preserved; but in the few specimens which contain no pyrite, the shell is crushed, deformed, and poorly preserved.

The replacement by silica, which seems to have been very rare in the Silica Formation, apparently could take place at any time after burial; it means nothing concerning the rate of burial.

Are fine details still present, or have they been worn off?

If the specimen was subjected to turbulence or to prolonged exposure to powerful silt-laden currents, it would experience appreciable wear on the finer details of ornamentation. Yet if the specimen was smooth, such abrasion may be difficult to detect. If several specimens of a long-tipped Mucrospirifer are discovered intact with their fragile points unmarred, we can safely presume that they were not moved far nor



... and keep on ...

buffeted by shallow-water turbulence. But if nearly all specimens are broken, we should look for confirming evidence of high energy in the environment.

On the other hand, epifauna and overgrowth of attached organisms are strong evidence for a period of post-mortem quiescence.

Item 5. General health and well-being of the fossil. How it was faring while still alive.

Were parasites infesting your species?

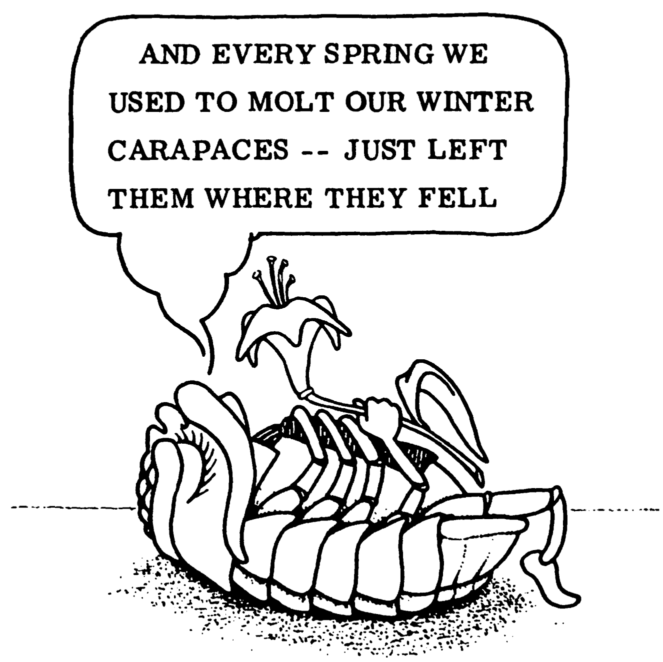
We might expect that in a population infested by parasites, a significant number of specimens would show the evidence. The number of fossils showing parasitism may be disproportionate to the actual number of infested individuals in the living population, because old and heavily infested animals were the ones most likely to die -- from direct effects of the parasitism or from the general debilitation it produced. Thus, the appreciable percentage of Paraspirifer bownockeri having the mantle-nibbling Cornulites still attached (often several along the anterior edge) may tend to overemphasize the overall impact of this parasite on the brachiopod population. The epifauna present on steinkerns of cephalopods (the bryozoan Reptaria stolonifera and the inarticulate brachiopod Petrocrania hamiltoniae) do NOT represent parasites, for obviously they merely inhabited the already vacant living chamber of the cephalopod and used it as a protected niche.

Are there deformities that represent old scars or wounds to your specimen?

The commonest scar on Paraspirifer is the boring probably produced by some sponge. The holes are aligned along a growth line on one valve and appear along the corresponding growth line of the other valve. Hence, we conclude that the infestation was intense at irregular and few intervals (an unwelcome rain of larval sponges) and that it was seldom fatal to the host (inasmuch as nearly all brachiopods survived to secrete shell material beyond the infested edge).

One brachiopod was found with a strongly asymmetrical shell which apparently resulted from one tip being bitten off when the animal was young. The deformed and scarred specimens reveal more about community health than the more nearly perfect ones, but many collectors ignore them.

We can also be certain that any Aulopora or attached bryozoan extending across the com-



.... and on and on ....

missure of a brachiopod did so after the brach was dead -- although it may well have begun its attached life while the host was still living.

Field Evidence

A whole tier of drawers in a museum filled with choice specimens may tell us less about the original environment that one specimen studied in place in the rock unit.

Item 6. Burial position.

Is your specimen found in what you can assume is its life position?

There is a world of difference between a corallum that is upright and one that is overturned in the stratum, even if they are exactly alike when extracted from the matrix. Field evidence alone can attest to the energy conditions involved in burial.

Some solitary corals are found with sections at fairly sharp angles, indicating that the coral was upset and came to lie horizontal, then changed growth direction to extend the new section upward, was upset again, etc. The overturning of such corals could have resulted from undercutting by increased velocity of currents, or from the sudden surge of a strong storm. Look for the number of specimens so affected, especially in the same stratum.

Are many specimens broken in the matrix?

Fossils which have not been buried deeply are always subject to the action of strong storms. Furthermore, if the currents mount in velocity they may reowrk an old deposit. Or a slight tilt in the local topography may lead to redistribution of sediments and their contents, or one turbidity current could alter the whole local topography.

Are specimens concentrated on one bedding plane?

If specimens of a species are particularly numerous in one bedding plane, and especially if the bed above is depleted or barren, we must look carefully at the specimens in the matrix. If most are in a logical living position, then we might suppose that the thriving population was suddenly smothered by an influx of mud. But if the specimens on the bedding plane are helter-skelter, with many upside down or broken, then we might be convinced that they were brought in and dumped by a strong current, or that they were the lag deposit remaining after finer particles were eroded away by currents.

Are the specimens of different horizons sorted by size?

Only a very few kinds of animals live as young in one envrionment and as adults in another. Instead, we find that for most animals all growth stages exist in the same community. So if we find little specimens in one bed and large ones in another bed, they can be presumed to have been sorted in transport. Different intensities of current would explain such selectivity.

Item 7. Lithology of matrix.

Lithology reflects energy and depth. Generally, the Paleozoic limestones are shallow-water deposits and display abundant evidence of turbulence; the soft shales are deeper and rarely show any such disturbances. So lithology itself may provide some insight into the paleoecology of the fossils it contains.

The limestones usually have fewer kinds of fossils, for not many animals could adapt to the constant buffeting by wave action, the uncertain and fluctuating salinity nearshore, the exceptional high tides (with suddenly increased depth) and low tides (with possible exposure to air), or the violence of storm turbulence. Only stromatoporoids, corals, and a few large brachiopods are commonly found in limestones. The shale fauna is varied, with the quiet water and normally slow sedimentation providing an ideal habitat for a variety of marine animals.

In highly saline deposits very few animals could adapt; the usual "loners" in brine are species of arthropods, although the one dominant species may occur in prolific numbers.

Is the species found only in one lithology?

If the species is always found in one lithology, then that kind of sediment was at least strongly preferred -- along with the conditions which accompanied its deposition.

Is the species present in many lithologies?

The species that occurs in all kinds of lithologies must be studied carefully in each. If it is about equally distributed in limestone and shale, and if it is equally well preserved in each lithology, then it may prove to have been truly ubiquitous -- at home in a variety of environments. If, however, it is much more numerous and much better preserved in one of the lithologies, that one may have been its homeland and the specimens in the other lithology may have been brought in by exceptionally strong forces or even reworked into the foreign lithology long after death.

Item 8. Paleogeography.

As we look at one collecting site, we may not be aware of all the factors influencing the fossil's environment. Even fairly distant physiographic and climatic features could affect the place where the fossil lived.

How close was the nearest reef?

By its origin and mode of growth, the reef has always been an unusual kind of environment. In close proximity are the realms of shallow-water turbulence and deep-water quiescence. The areal concentration of environments and the telescoped distribution of depths made the Devonian reef the arena for a number of unusual kinds of animals from all ways of life -- predators, scavengers, fast-breeding members low in the food pyramid, and entrepreneurs making a precarious but satisfactory living in little ecological niches.

The areas around reefs sometimes contain unexpected species distribution patterns as a result of the currents and their food content, with here and there even barren patches between reefs.

Where was the nearest beach?

The direction of shallower and deeper water may explain something of the distribution of your particular species. Such information is essential in working out the vertical (time) distribution of the species in transgression or regression of the sea.

Are the specimens aligned by currents?

The elongate fossils, such as Tentaculites, Styliolina, or certain bryozoa, may occur all parallel on an exposed bedding plane. Since they had no reason to live with such a preferred orientation, it seems obvious that they were laid out in this pattern by currents after death. Unfortunately, it is seldom possible to study the fauna on a single bedding plane over a wide area, so the information is of limited use unless we study the orientations on many bedding planes in the stratigraphic succession.

There is also indirect evidence of the presence of currents. Benthonic filter-feeders, such as edrioasteroids, crinoids, or blastoids, could only survive where the currents brought food past their anchorage on a regular schedule.

Were there evaporites at the time your fossil lived? How close?

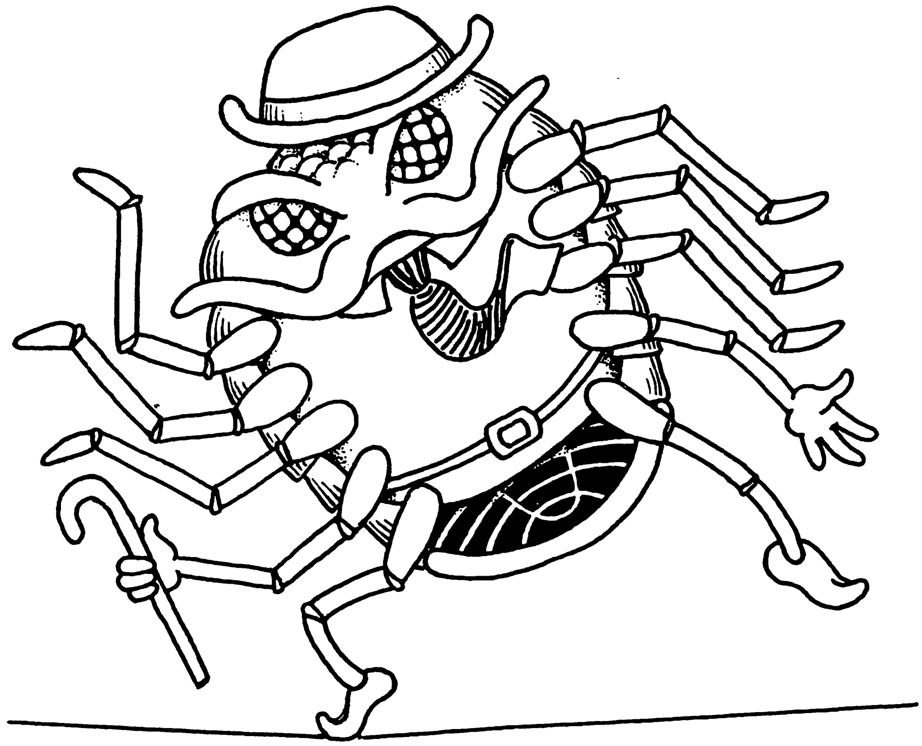
Evaporites in the past, like those in the present time, are good indicators of dry conditions. When the Silica Formation was being deposited, western Michigan was the site of evaporation that produced gypsum. As we now believe, this basin of evaporites was cut off from the Silica sea by a barrier, probably a carbonate reef or bar, and did not affect the salinity of the waters in which our fossils lived. Nevertheless, it could have exerted some influence on the life of the time, for land deserts can supply very little organic debris to the seas nearby. Whether this had any effect as far east as the Silica region could be questioned. It is likely that the base for the Silica food chain was microscopic photosynthetic organisms in the surface layers of the sea.

How extensive is the lithology in which your fossil is found?

If the bed in which your species is found is very thin and the only one of its kind in that part of the section, we would like to know from whence the lithology came. It is certainly true that the benthonic organisms follow one lithology throughout their lifetimes and even throughout the history of their species, as a matter of life or death. The direction in which such a thin stratum expands is likely the direction from which it came into the area and to which it retreated -- bringing in and taking with it the associated fauna.

Was your species a swimmer, crawler, or floater? Was your species anchored or vagrant?

If your species was an active swimmer, it could be totally independent of the sediment being deposited on the seafloor below. The cephalopods fit this category, to a great extent; they may have settled on the bottom for feeding time, but they could travel to a different area of sediments at will. The crawling trilobites could make their way to better grazing grounds, but with more effort. The sedentary and bottom-bound corals had no such choice, and at the place they attached as larvae they either made a living or expired. Hence, the lithology did not mean as much to some animals as to others.



With insistence and perseverance, you can almost bring your fossil back to life ...

All Museums and Literature

If we are serious about understanding our species, we would be remiss if we did not take advantage of all the information available in all museum collections and in published literature.

Item 9. Distribution of the species. Everywhere it can be found.

Is the species present in other states, other continents, or other formations?

The total distribution of your species may surprise you. In the past, to our present dismay and confusion, paleontologists were anxious to commemorate each occurrence as a new find and therewith created excess species names.

The recent discovery of continental drifting and global tectonics incites us to compare our North American Devonian species with those that have been described from Europe, for in the mid-Paleozoic they were essentially one continental mass. Search the literature for possible synonyms for your species.

Because fossils have such importance for correlation, examine carefully the fossils listed and described from other formations.

Where were the continents at the time your fossil was alive?

Our fauna comes from a shallow sea in North America. Were there shallow seas of similar depth in other areas, we should look for our faunal elements in them. Again, the literature is the starting place for investigation.

Were individuals of the species closely packed together or widely separated?

Heavy and attached animals, such as the corals, have a density according to the excellence of living conditions. Only in very favored situations, as in the area of Medusa North Quarry, did any of the Silica corals find a situation close to ideal; there the auloporoids built the mound with their skeletons, which could be called a thicket and which approaches a reef. Brachiopods, whether actually attached by a pedicle or not, were only moved about by strong currents. The number per square meter is a measure of their original population density, provided they are most in what can be attributed to the living position. On the other hand, cephalopods were probably dying or dead when they came to their final resting place, and the spacing between specimens is not significant.

Is there a common factor in the various occurrences of your species?

Determine if your species always occurs in a particular association with certain other species. Or if it was always in a particular relationship to paleogeographic provinces, such as distance from shore or flanks of reefs.

Was the environment one of high or low energy?

Look closely at rock features which might give away the energy level of the environment. Algal mats in the associated matrix would indicate quiet conditions; oolites would indicate frequent and regular disturbance sufficient to lift the individual grains. As already pointed out, the lithology itself is a sign of the energy.

Can you determine any survival factors for the populations or for the individuals?

This is in part a study of where the species did NOT live. Does it appear to have been restricted by depth, by the rate of sedimentation and size of particles, by the calcareous content of the matrix, or by certain faunal associations? All of these could be looked at separately.

Item 10. Variations in populations. How the specimens from widely separated exposures differ from each other.

Are there dwarfs in any particular occurrences? Or giants?

Many invertebrates continue to grow as long as their general health and digestion function. It is to be expected that for some kinds of animals, conditions at one place will be far superior to those at another and that the residents of the first place will attain significantly larger size. Conversely, some species will be able to survive in adverse circumstances; they may attain their old age at a size comparable to young individuals at a preferable locale. One of the most difficult decisions to make in paleoecology is to distinguish the size differences due to the growth of the individuals in two environments from the differences introduced later by current sorting.

Does one population have significantly larger, smaller, fatter, slimmer, thicker, or thinner individuals than another?

It is important to note (if not explain) the variations in proportions of the animal's dimensions in two populations. Some paleontologists are satisfied to call attention to consistent differences in the two populations by creation of subspecies. Even though our paleontologic method of classification must be based on morphologic characteristics, we should at least try to lend our taxonomy a semblance of genetic reasoning.

If so, what are the other community members like in each of the two differing populations?

When all the other species present in two collections show size sorting, we must be suspicious of mechanical current sorting as the responsible agent. Thus, if we find the small tabulate corals (sessile) and the trilobites (vagrant) both sorted into large and small collections, we would favor current sorting.

While we are reading what others have noted about our species and examining the collections in various museums, we can keep a few other questions in mind:

How did the species solve the problems of support on the bottom sediment?

This can be an intriguing project for the sessile animals. Among the corals, for example, the horn corals were naturally pointed at their initial end and appear to have driven themselves downward into the soft substrate by their weight -- a self-spiking organism; the auloporoids and their relatives let other organisms do the problem-solving by early attaching to their shells; and the little "pin-cushion" coral Pleurodictyum (Procteria) cornu spread laterally, floating on the muddy bottom like a pancake. Among brachiopods, some of the thin species retained a pedicle throughout life, a flexible stem capable of thrusting the shell above the accumulating mud; the large rotund Paraspirifer bownockeri seems to have kept at the surface of the sea floor by its great width and perhaps aided by the opening and closing of its valves.

Was there a significant change in morphology during the animal's lifetime? Did the young look like the adults?

Some invertebrates go through a change part way through their lives, changing their proportions and sometimes even their diet. The trilobites increase the number of thoracic segments, among other things, during early ecdysis (molting) changes. Solitary corals add to the number of septa. In other animals, the alterations are sometimes more subtle.

Do the largest specimens exhibit any peculiar structures that might indicate "senility" or a gerontic phase?

Old age is the end of ontogeny. Growth may slow down, so that the spacing of growth lines on a brach or clam may diminish as it gets old. Ornamentation may become more pronounced. Some animals seem to have kept their shells free of epifauna until they were advanced into maturity.

Perhaps other questions occur to you in the complicated interrogation of the fossil witness.

Summary

Briefly, we can learn from museum specimens something about a fossil's

1. Identity,
2. Population of its species,
3. Community structure,
4. Preservation, and
5. General health and well-being.

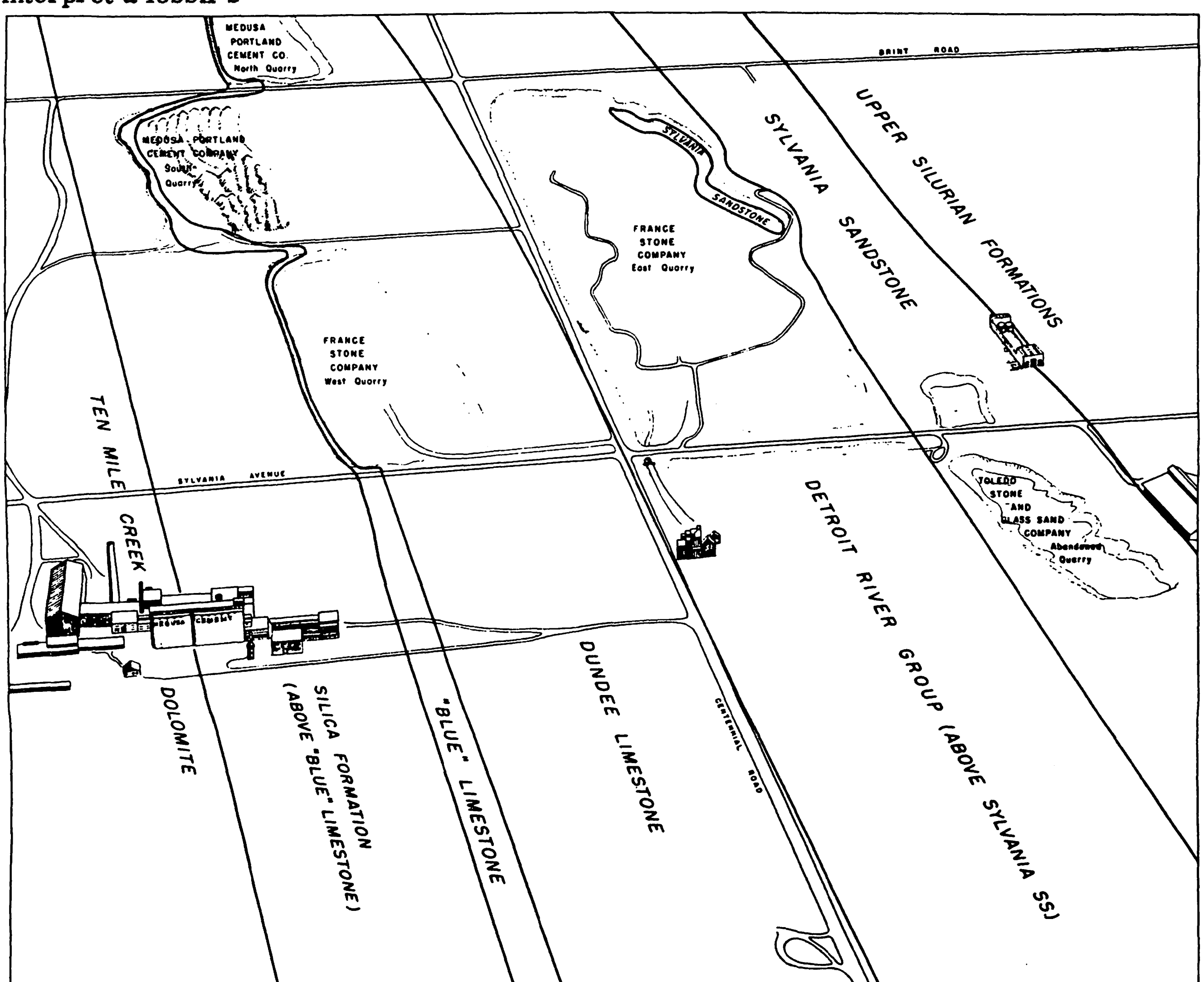
From field observations we can study and interpret a fossil's

6. Burial position,
7. Lithology of matrix, and
8. Paleogeography.

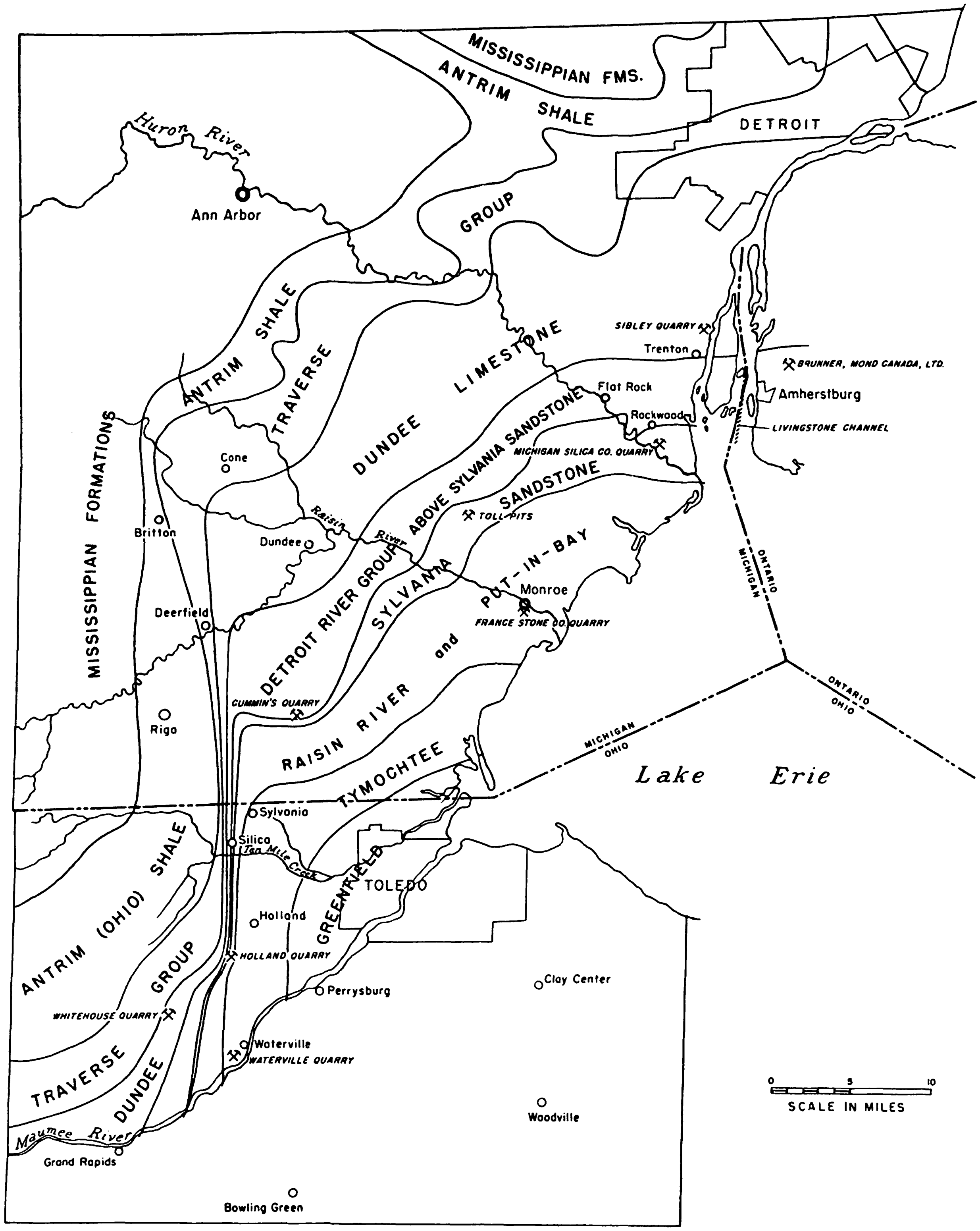
From all museums and published reports, we can investigate

9. Distribution of the species, and
10. Variations in populations.

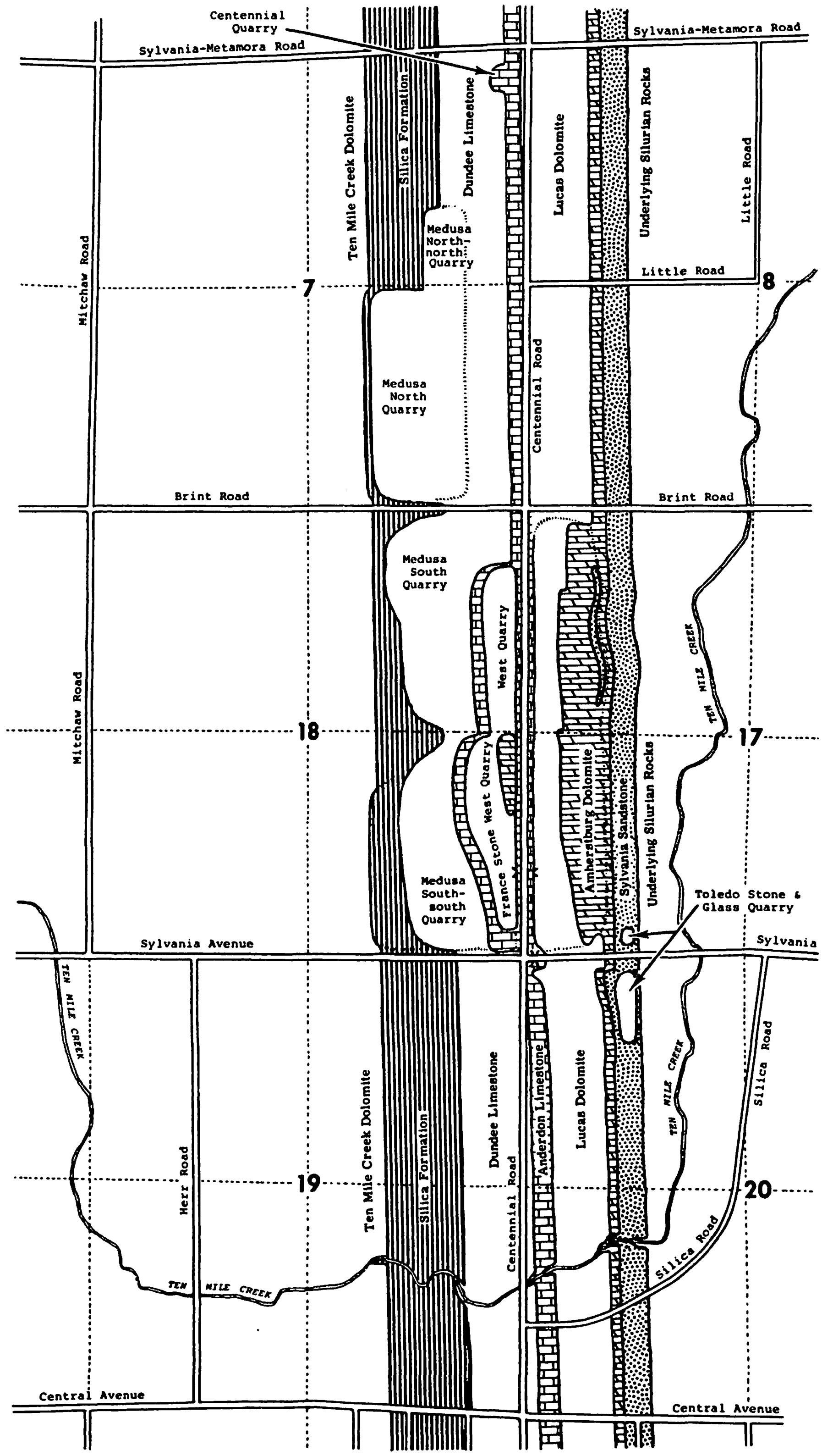
Although the fossil animal actually experienced environmental conditions in the distant past, its preserved parts may not proclaim in unmistakable terms just what those conditions were. A fossil species may be very reluctant to reveal its day-to-day routine, its habits of eating and respiring, its relationships to others of its kind, it position in the community, or its movements within its territory. And yet, that is one of the reasons why paleontology can still claim to be a fertile field for research -- for years to come.



Sketch from aerial photograph, quarries labeled, Ehlers, Stumm, and Kesling, 1951



TEXT-FIG. 2 -- Geologic map of southeastern Michigan and northwestern Ohio, showing the narrow belt of formations along the Lucas County Monocline. From Ehlers, Stumm, & Kesling, 1951.



TEXT-FIG. 3 -- Detailed geologic map of Silica, Ohio, area, with formational boundaries and quarries as they were in 1974.

MR. VALIANT'S TRILOBITES

Thomas E. Whiteley
105 White Village Drive
Rochester, N.Y. 14625

On September 24, 1892 William S. Valiant accompanied by his half-brother, Sid Mitchell, found a trilobite with perfect, pyritized antennae projecting from the cephalon (head). This was not a chance find as Valiant had been seeking this prize in the immediate area for eight years. The trilobite was *Triarthrus eatoni* (Hall), common to both the Upper Ordovician Frankfort shales, in which he was searching, and to the underlying Middle Ordovician Utica shales, both widely exposed in central New York.

What prompted this long search was, that although trilobite legs and gill-like structures had been described by C. D. Walcott in 1879 from specimens in the Trenton limestone, no one had definitively demonstrated antennae on these animals. Valiant believed that they must possess antenna because of their similarity to modern crustaceans and so began his quest. The particular site, for this search, was chosen because Valiant thought the fine-grained deep water sediments would yield trilobites which were not broken up by wave action. In the course of this extensive search he found specimens "showing imperfect legs, but not the antennae we were after". (Valiant, 1901)

Fortunately the story doesn't end here as the same specimen with the antenna also showed perfectly preserved legs and associated fringed gill-like structures, also preserved in pyrite. Further digging revealed Valiant had discovered a bonanza. Within a thin, about 3-5 mm, layer in the trilobite bed there were large numbers of remarkably well preserved Triarthrus, along with the trilobites *Cryptolithus bellulus*, *Cornuproetus beecheri* and *Primaspis crosotus*. (None of these latter trilobites were even close to the *Triarthrus* in quantity and quality of preservation.) This site has to rank as one of the first discovered Lagerstätte with the conservation of soft-tissues in North America.

W. S. Valiant was an amateur collector of natural history specimens known to the paleontologists of that time through correspondence and fossil sales. He evidently contacted a number of people including James Hall, the State Geologist of New York, about his remarkable find but received no replies. It wasn't until a Mr. Kingsley of Rome, N. Y. contacted Prof. Kemp at Columbia College (now Columbia University) that some of his specimens were purchased and examined. Prof. Kemp turned this task over to a student of his, W. D. Matthew, who described his observations in a paper before the N.Y. Academy of Science in May of 1893 and published them in July and August of the same year. It was these papers which undoubtedly attracted the attention of the paleontologists. Prof. O. C. Marsh, of Yale College, similarly purchased specimens which he turned over to a junior colleague of his, C. E. Beecher, who then published descriptions of the trilobites in November and December of 1893. C. D. Walcott, then with the U. S. Geological Survey, visited Valiant and his quarry in 1893 and published his own examinations of Valiant's and his own collected material in March of 1894.

Beecher followed up this initial interest with the quarrying of two tons of the fossil stratum in the summer of 1893 and then, until his untimely death in 1904 at the age of 48, prepared the *Triarthrus* by exacting techniques which he had to develop. It is Beecher's work which is most often quoted and illustrated, to the point where Valiant's locality for these remarkable trilobites became known as "Beecher's Trilobite Bed".

Significant collections, and *Triarthrus* preparations, were also made by C. D. Walcott from visits to the site in 1893 and 1895. In the latter year 274 sq. ft. of trilobite layer were excavated for the U. S. National Museum. Walcott estimated he moved 365 cubic yards of shale (Collier, 1990). This was accomplished in six days with the aid of four laborers for three of those days and two laborers for one additional day. (Walcott, 1895) There is also reported to be 300 pounds of material in the Museum of Comparative Zoology at Harvard University (Cisne, 1973). Valiant estimated that in all five thousand specimens were taken from the quarry during all this time. Most of this initial work was thoroughly described in a memorial monograph, to Beecher, in 1920, written by P. E. Raymond of Harvard University. Raymond also reexamined much of the original prepared material and offered his own interpretations on some controversial issues. Raymond also had Beecher's original model redrawn with some slight changes- "modifications are taken principally from figures published by him" [i.e. Beecher]. (Raymond, 1920)

Its difficult to imagine the incredible care and painstaking attention to detail that went into Beecher's work during the eleven years he examined this material. He quickly found that the normal methods for fossil preparation, both chemical and physical, were too harsh to distinguish the pyrite film, constituting the fossil, from the shale matrix. After what must have been a great deal of trial and error he finally found that by abrading the matrix away with abrasives applied with pieces of rubber he was able to reveal the hidden details. Very fine detail required that the rubber was cut to very fine points. Beecher became extremely expert with this technique to the point where he sometimes revealed both sides of some specimens in paper thin preparations. In all it is reported he worked "on several thousand specimens, each one which revealed something of the ventral anatomy. Finally some 500 specimens worthy of detailed preparation were left, and on about 50 of these Beecher's descriptions of *Triarthrus* and *Cryptolithus* were based." (Raymond, 1920)

No further detailed investigations of the remarkable *Triarthrus* from these beds were made for over fifty years until a student at Yale, John Cisne, published his senior research paper on the Beecher's Trilobite Beds in 1973. Cisne followed this initial report with a series of papers on *Triarthrus* for his doctoral dissertation, at the University of Chicago, based to a large extent, on very high quality stereo radiographs of Beecher bed material which revealed information invisible to surface examination. Cisne also attempted, without success, to find the original beds. The most recent interpretation of the material obtained in the last century is that of Harry Whittington and John Almond (published in 1987) with painstakingly reprepared specimens and camera-lucida drawings from specimens immersed in alcohol. In all this there were no specimens available or reported from the site after 1895 when it was reported to be "quarried out".

The 1973 Cisne paper stimulated the author and his son, Brian, in the early 1980's, to attempt to relocate the original Valiant site in "Clevelands Glen on Six Mile Creek" north of Rome, N. Y. Two summers of casual searching gave us a good perspective on Six Mile Creek but no definite site at which to dig. In 1984 the author was joined by Dan Cooper, from Cincinnati, Ohio, in this quest. Using a good guess at what a heavily quarried site in this shale might look like after 90 years of weathering and regrowth of vegetation, we found a likely site which had the right look. That fall we dug a test hole and indeed the original quarry floor was about eight feet down and a pyritized *Triarthrus* was quickly found in the layer immediately above this quarry floor. (This is undoubtedly where Walcott finished in 1895.) The land owner was contacted he graciously agreed to allow us to dig a larger area, a project carried out in 1985. Moreover the land owner brought in a bulldozer to move the overburden more effectively, which then allowed the use of a back-hoe to clean down to where hand work was necessary. The agreement with the land owner was, and is, that this was not a commercial venture and if the site was still productive we would bring in any interested professional paleontologists.

The Trilobite Bed material removed from the site at that time remained in the author's garage, essentially untouched, for about two years as his job took him to England during 1986. When work on this material resumed in

1987 it was immediately evident that the bed was not quarried out and significant numbers of the appendaged trilobites were available. Fred Collier, Collections Manager for Paleobiology at the National Museum of Natural History (Smithsonian), was aware of this find from our earliest test holes and he passed the information along to Niles Eldredge at the American Museum of Natural History and a student of his, Greg Edgecombe. Edgecombe visited the author to look at some of the material and returned to the museum with specimens in which he was interested. These specimens were then donated to the American Museum. It was clear from all this that the site is still productive and the material is significant.

In 1988 Collier put together a joint effort of the National Museum and the American Museum to quarry the site in the following year and he obtained the land owner's agreement to allow the National Museum to control continued access to the site for the purpose of removing fossils. Derek Briggs from the University of Bristol (England) also joined the dig with a view to determine why the remarkable preservation occurs. His work is collaborative with Rob Raiswell and Simon Bottrell of Leeds University who are analyzing the isotopic composition of pyrite in the sequence and in the trilobites themselves.

Site preparation required the removal of approximately 25 feet of shale before the fossil layer could be removed. The fossil layer was removed in slabs about 3 inches thick for subsequent work-up at the respective museums. Briggs removed a continuous sequence of samples from the section from above and below the beds for his research. In the three weeks of actual quarrying 26 boxes of fossil bearing rock were removed for the museums, and the site was reclosed.

Having reviewed the history of the site to the present day one must next turn to the question of why this site is important and unique enough to be considered a Lagerstätte. Evidence of trilobite appendages is no longer a unique event. Indeed P. E. Raymond in his 1920 monograph discussed a number of the specimens then available which displayed these parts of the now extinct animal. There are more than thirty Paleozoic sites world-wide with significant soft-body preservation. However, preservation of this kind in pyrite is rare and worthy of further study. One should not, however, consider that these sites all yield trilobites. For further information one should refer to the newly published of book of Allison and Briggs (1991).

Beecher's Trilobite Bed yields not only large numbers of the appendaged *Triarthrus* but also splendid three dimensional graptolites, trace fossils, numerous cephalons of juvenile *Cryptolithus*, protaspides (early growth forms) of at least three trilobites and the other rarer, whole, preserved trilobites mentioned earlier. The protaspides are particularly interesting. Edgecombe does not believe that any of them are the protaspis of *Triarthrus*.

Beecher's research on the *Triarthrus* material resulted in the publication of the splendid drawings of the dorsal and ventral views of the exoskeleton, complete with appendages, and other details so often reproduced in historical geology and paleontology texts. (figures 1a,b,c) There have been at least five published studies on the material since these original drawings. Walcott in 1918, Raymond in 1920 and L. Størmer in 1939, each made minor revisions of the previous published work. Cisne in 1981 not only made changes in the details of the exoskeleton, for example, the reduction in the cephalic "legs" from four pair to three, but also suggested a significant amount of the internal anatomy. The most recent work, that of Whittington and Almond (figures 2a,b,c), brought the model up-to-date, offered corrections to some of the earlier reconstructions and introduced an increasingly three dimensional character to the final model which is not fully emphasized in the previous reports.

Since all these workers were working from essentially the same material, one might ask the need for so many revisions. Three factors which figure prominently in the changes are first, that although the available specimens are remarkable in the information they convey they are still fossils, no one of which is so perfectly preserved to offer a lifelike appearance. The cleaning and preparation of this exceedingly delicate pyrite film could well have introduced artifacts. Since each restoration is a composite of a number of specimens the researchers had to build a model and fill in the "blanks" as best they could. The second reason is that each succeeding scientist who studied this material had not only the previous work and specimens to which to refer but also all the relevant preceding paleontological studies throughout the world to reference. The earliest studies because of lack of information were probably biased more by structures in existing Crustacea than present knowledge would warrant. Thirdly, with the passage of time new technologies and techniques, such as stereo radiography and isotope analysis, present additional opportunities for new information and interpretations.

Figure 3 is from the work of Beecher and Raymond and demonstrates the possible ventral structure of *Cryptolithus* taken from unpublished Beecher material and Raymond's own restoration models. There were only thirteen specimens and partial specimens of *Cryptolithus* with appendages available and they are quite incomplete by *Triarthrus* standards.

Note that in all this the "legs" are biramous or forked, into an endite which appears to be a lower walking or crawling member and an exite which because of its fringed appearance suggests a breathing organ. Biramous appendages have been observed in other Ordovician trilobites found in New York such as *Triarthrus*, *Flexicalymene*, *Ceraurus* and *Cryptolithus* but only the endites have been reported on *Isotelus* and *Primaspis* although there is no reason to believe that they did not have the exites.

The original Beecher model also had four pairs of biramous appendages on the cephalon in addition to the uniramous antenna. This interpretation may have influenced workers for some time as numerous reconstructions of *Olenoides*, *Triarthrus*, *Flexicalymene* and *Ceraurus* all showed the requisite four pairs and this was considered the norm. Whittington's work in 1973 on *Olenoides* and the already referenced work of Cisne changed this and three pairs of biramous appendages on the cephalon is possibly the "standard" trilobite structure. There is one pair of biramous appendages on each thoracic segment and this too is general. The pygidium is different and just as there is a wide variation in the relative size, shape and segmentation of the pygidium in trilobites there is undoubtedly wide variation in the number of associated appendages- but their morphology is apparently the same as that of the thoracic appendages.

Details of the musculature discussed by both Cisne and Whittington and Almond are unnecessary for this paper but Whittington and Almond's model makes some interesting points. They conjecture that the pairs of legs on each thoracic segment move in unison or in phase. Thus walking may have resembled that of millipedes and many familiar centipedes where leg movement is an in-phase, wave like appearance down the length of the body. *Triarthrus* is also seen by them as a deposit feeder, scavenger and predator, however the details of conveying food to the mouth are unclear.

Cisne reconstructed the digestive system to one which is consistent to what was already known or conjectured of trilobite internal structure. The mouth is located on the posterior edge of the small, and rarely preserved in *Triarthrus*, hypostome which is attached to the front ventral edge of the cephalon. The stomach is in the cephalon and a cylindrical gut leads through the center of the thorax to the anus situated somewhere near the end of the pygidium.

The *Triarthrus* from this remarkable site have already afforded us with perhaps the most complete details of an individual Paleozoic animal available, and more is sure to come from the new material. This is most certainly an important Lagerstätte and a national treasure.

ACKNOWLEDGEMENTS- One must acknowledge the leadership and skill of Fred Collier in developing the funding and assembling the resources necessary to make the 1989 quarrying of Beecher's Trilobite Beds possible and successful. There are now three major quarrying operations of record for this site, Beecher (1893), Walcott (1895) and Collier (1989). Derek Briggs and Greg Edgecombe read early drafts of this paper and made a number of very helpful comments and editorial suggestions which strengthened the paper and were incorporated in the final draft. Derek also called attention to the Allison and Briggs (1991) reference which was just published.

February 12, 1991

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EXPLANATION OF THE FIGURES:

Figure 1a- Drawing by Beecher(1895) of a prepared *Triarthrus*. This is a large specimen, approx. 3.75 cm., and demonstrates the preservation available to him. It's not clear from the photographs published by Raymond exactly which specimen this is in the Yale collection.

Figure 1b- The classic dorsal and ventral reconstructions of Beecher (1896).

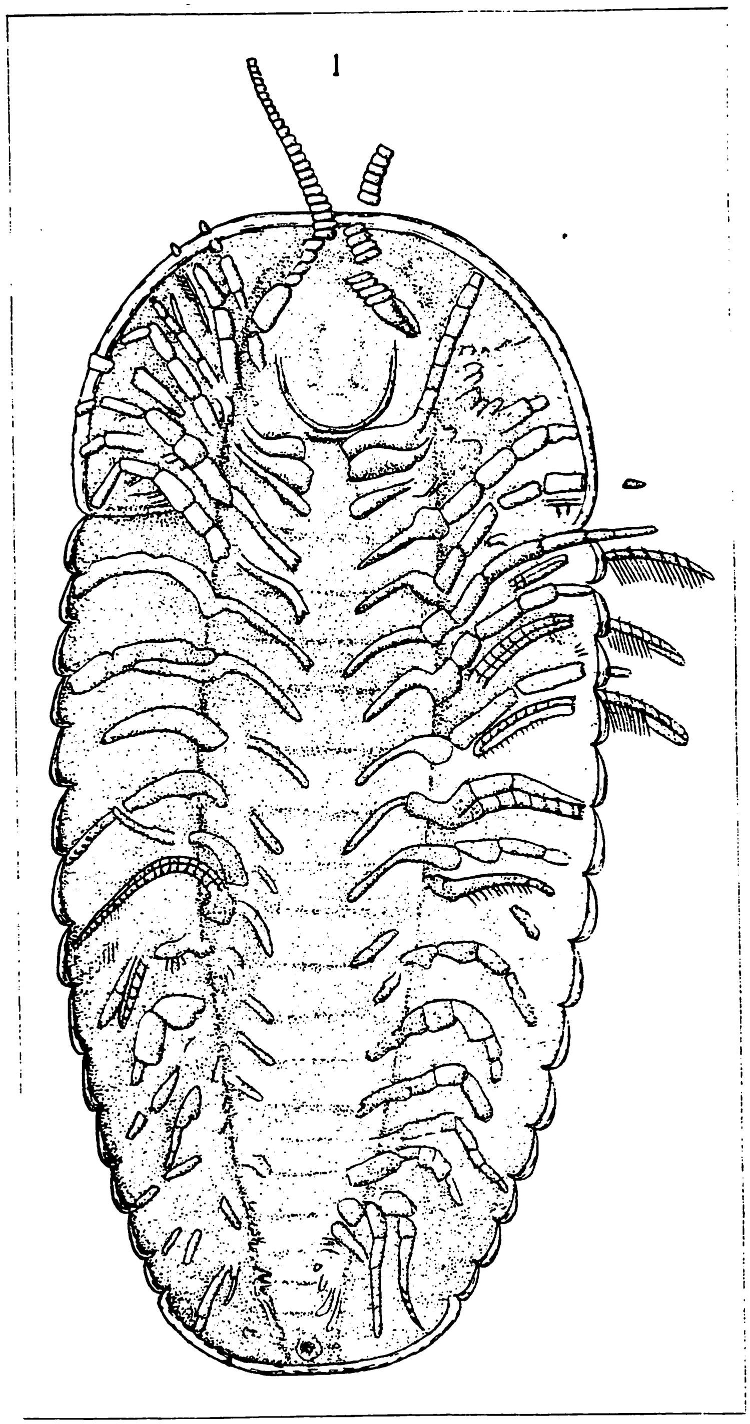
Figure 1c- Detail drawings by Beecher (1895) of cross-sections and the biramous appendages.

Figure 2a- Copy of figure 38 of Whittington and Almond showing their current model of *Triarthrus eatoni* exoskeleton.

Figure 2b- Copy of text figure 39 with cross-sections and a lateral view of the *Triarthrus* model in 2a.

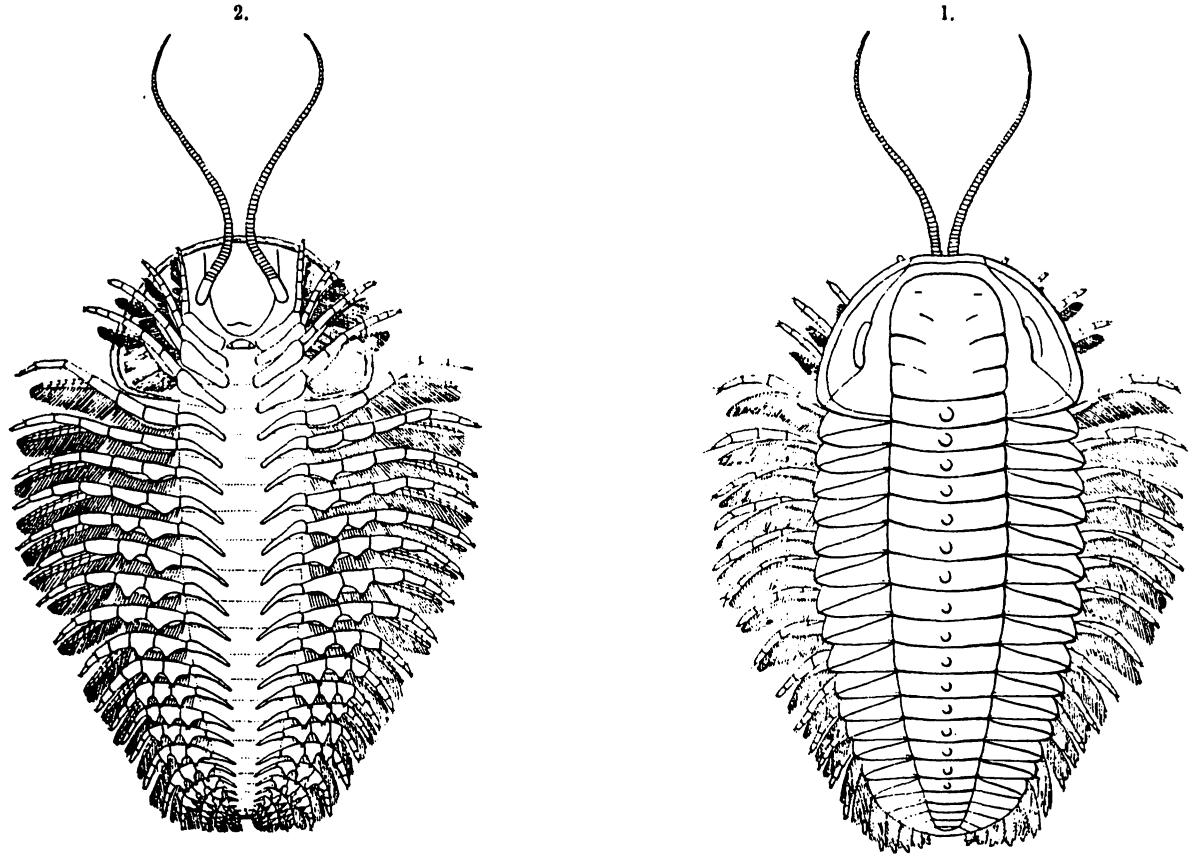
Figure 2c- Details of the biramous appendages in 2a.

Figure 3- Ventral reconstruction by Raymond of *Cryptolithus bellulus* from Beecher's Trilobite Beds using unpublished work of Beecher and Raymond's own observations.



VENTRAL STRUCTURE OF TRIARTHRUS.

FIGURE 1a



Triarthrus Becki Green. × 2¼. (Beecher.)

FIGURE 1b

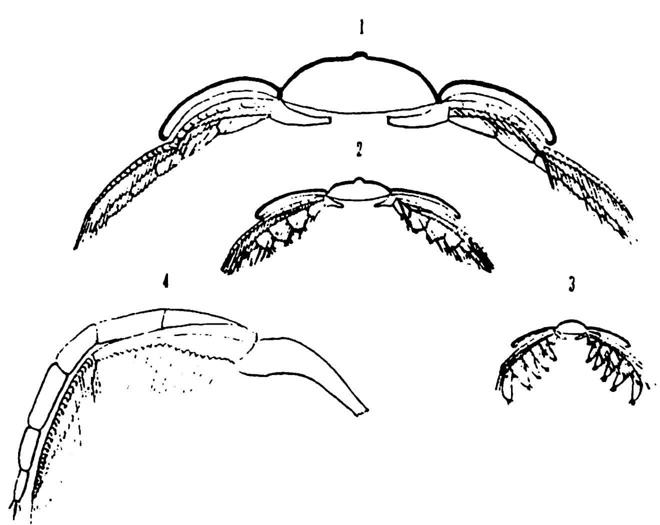


FIGURE 1c

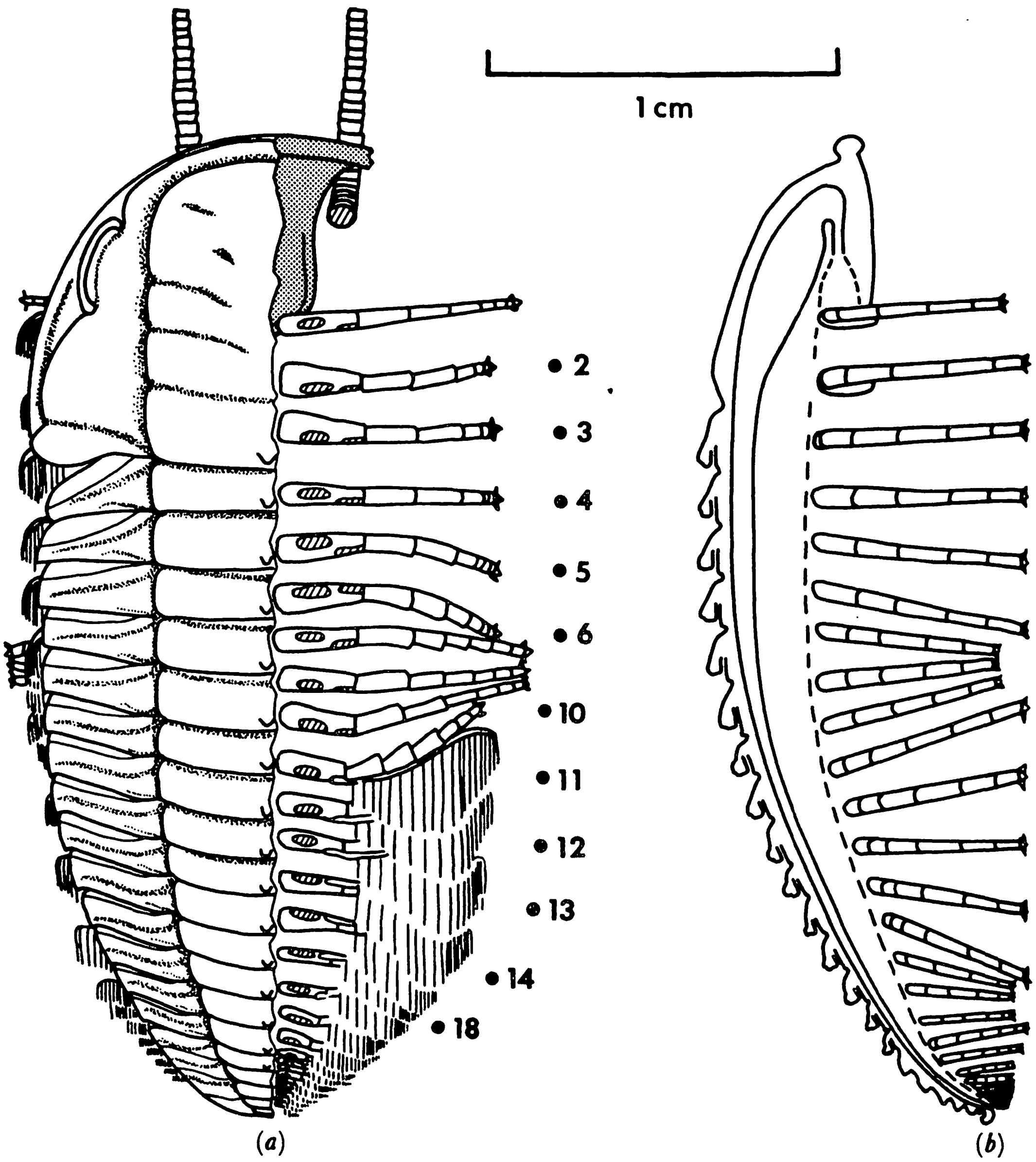


FIGURE 38. Restoration of *Triarthrus eatoni*. (*a*) Dorsal view, in 'still' position of gait (§6*j*), exoskeleton of right side removed to show hypostome and appendages (antennae incomplete). Exite of right biramous limbs 1–9 removed to show attitudes of leg branches. Solid circles and numbers opposite tips of leg branches on substrate, diagonal shading on coxa–body junction and at base of exites where removed. (*b*) Right lateral view of sagittal section combined with right leg branches. Coxae except those of limbs 1 and 2 not shown. Dashed line indicates ventral cuticle, alimentary canal in solid outline.

FIGURE 2a

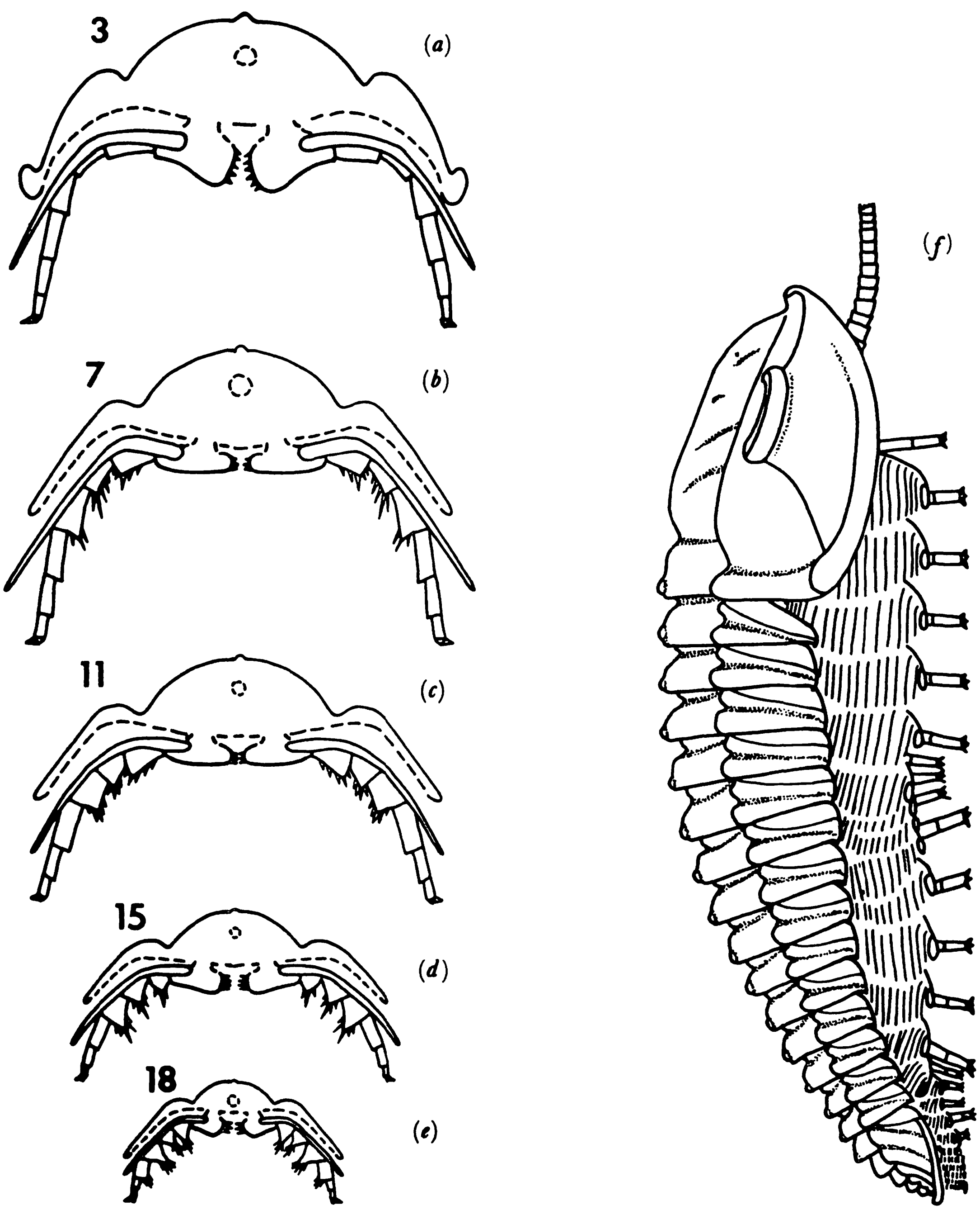
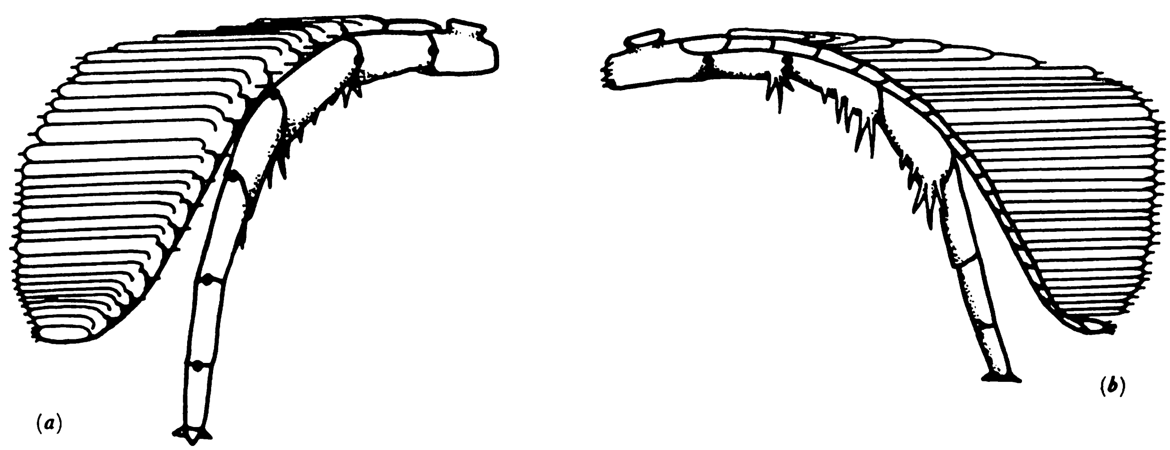


FIGURE 39 (*a–e*) Restoration of *Triarthrus eatoni*. Cross sections through exoskeleton, showing biramous limbs of series, as numbered, in posterior view, leg branches are vertical. Dashed lines indicate ventral cuticle and section through alimentary canal, filaments and division of exites omitted. (*f*) Restoration of figure 38 in right lateral view, exoskeleton complete and all exites shown diagrammatically.

FIGURE 2b



. Restoration of biramous limb of anterior thorax of *Triarthrus eatoni*

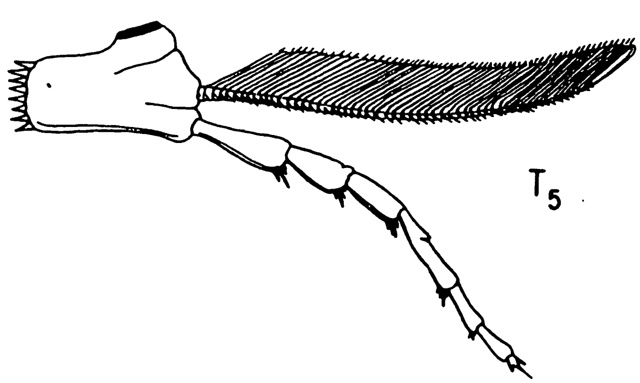


FIGURE 2c

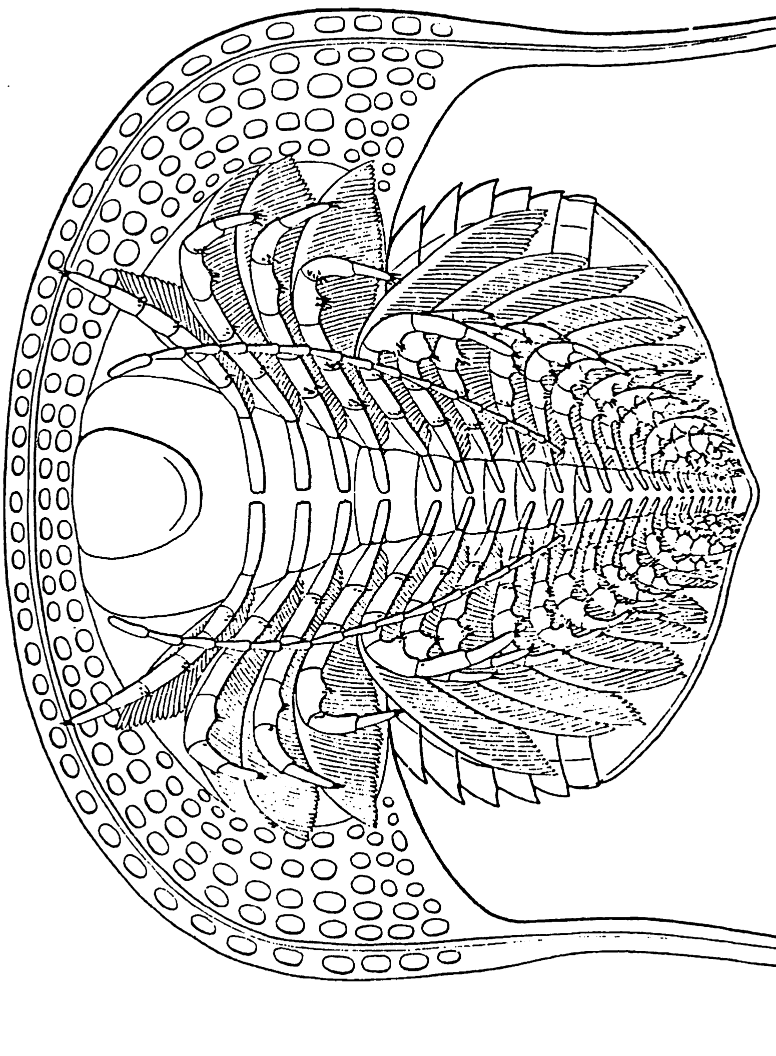


FIGURE 3

43

CHRINOIDS (CRINOIDS) ON GOTLAND

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The most common fossils you can find on Gotland are the small, round, flat, perforated plates and cylinders of different diameters. They are all drilled through by a longitudinal central channel. The fragments are parts of stalks from chrinoids (sealillies).

When Gotland was situated near the equator during the Silurian age, about 400 million years ago, most sealillies lived in large numbers on the floor of the warm shallow seas.

The name chrinoids comes from a Greek word "Krinos" that means lily, because of its beautiful flower-like appearance The chrinoids are animals. That is not difficult to understand if you have ever seen one. The small body with the long arms (crowns) makes it look like a flower's perianth and petal; you can also find the "stalks" and the "roots".

Chrinoids are and have been a pure marine being. They can be put in two main groups: The fixed chrinoids with "roots" and the chrinoids without "roots" that are closely related to our present living graceful Antendon (Anthers). The last group of chrinoids could move actively. There are approximately 5500 fossil species and almost all of them had roots and were fixed.

The size varied among the chrinoids. The smallest adult is a maximum of 1/8 inch long. The largest known form (from Jurassic age, about 185 million years ago) had an armspan of about 8.2 ft. and stalk length of about 65.6 ft. Today the largest living sealillies have a stalk length of about 3.3 ft.

The chrinoids, both the fossil and the now existing, have an inner very porous skeleton of lime. They are built of small sheets or plates. Inner organs are within the bowl-shaped calyx covered by a more or less elastic cup, "tegmen", where mouth and anus are. From the circumference of the calyx emerges arms that can be single or divided. The stalk consist of a series of plates perforated by a longitudinal channel. This channel continues out to the ends of the cirri, the outgrowth that begins in the lower end of the stalk which anchors the animal to the bottom.

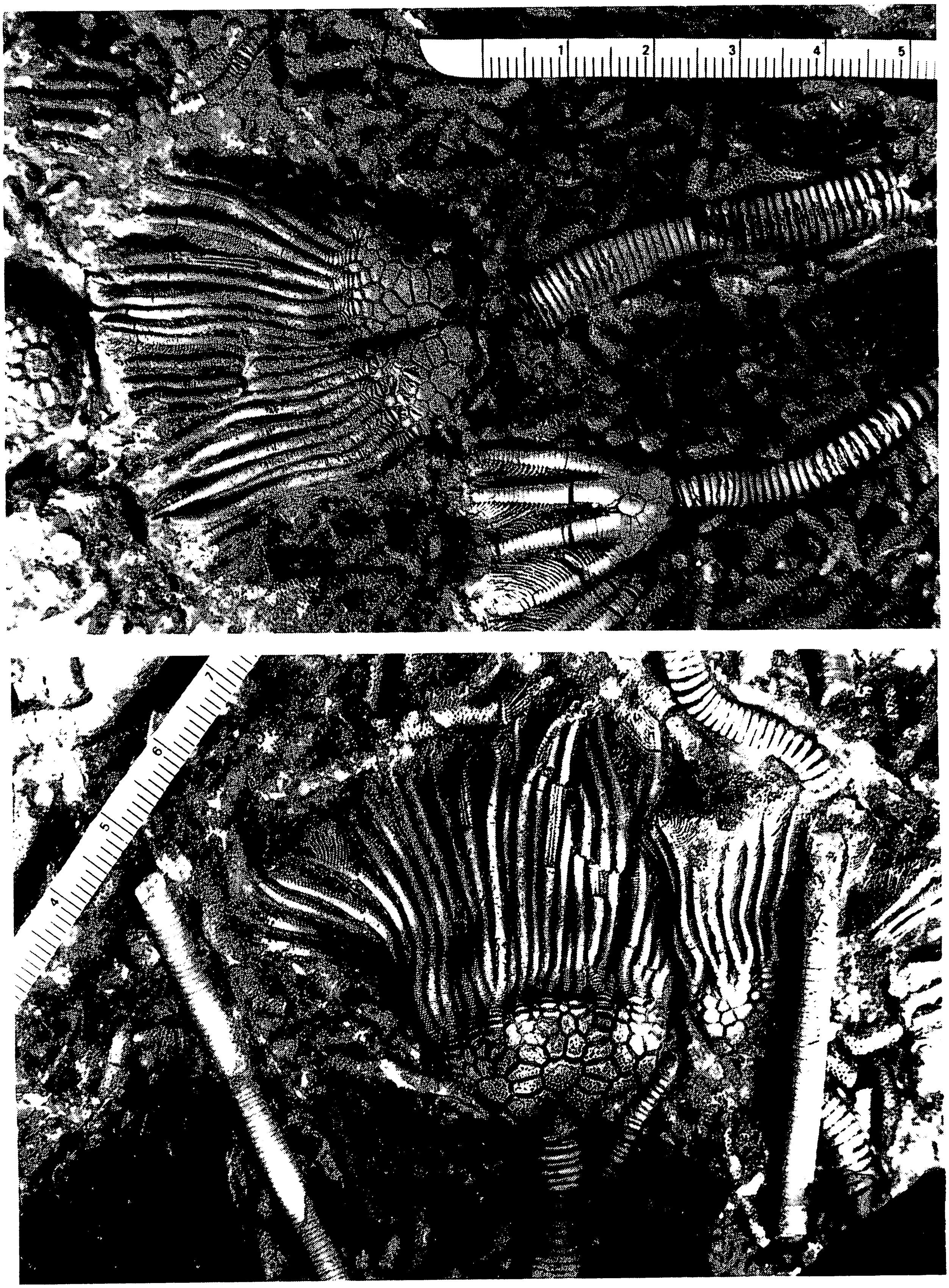
The particular skeleton elements are connected to each other through connective tissue. When the animal dies, the skeleton disintegrates very quickly, often within a few days. That is the reason why it is so seldom you can find a fossil chrinoid that is intact. chrinoids in good condition assums exceptional death circumstances. After death the animal must be covered with protecting mud, so thick that byrrowing organisms that lives on carcases or mud (for example mollusks and worms) cannot have the possibility to reach them. Which means the chance that everything will fit in place is very little!

In Nar - County on Gotland they have found a limestone plate 11 sq. ft. which has 260 pieces of sealillies, more or less in good condition on the upper surface. They are part of 4 different families. The chrinoids were buried alive, maybe in a storm or earthquake that put the mass of sediment in movement. The limestone plate is today in Stockholm at the National Museum, where they have taken great pains to prepare the sealillies for exhibition.

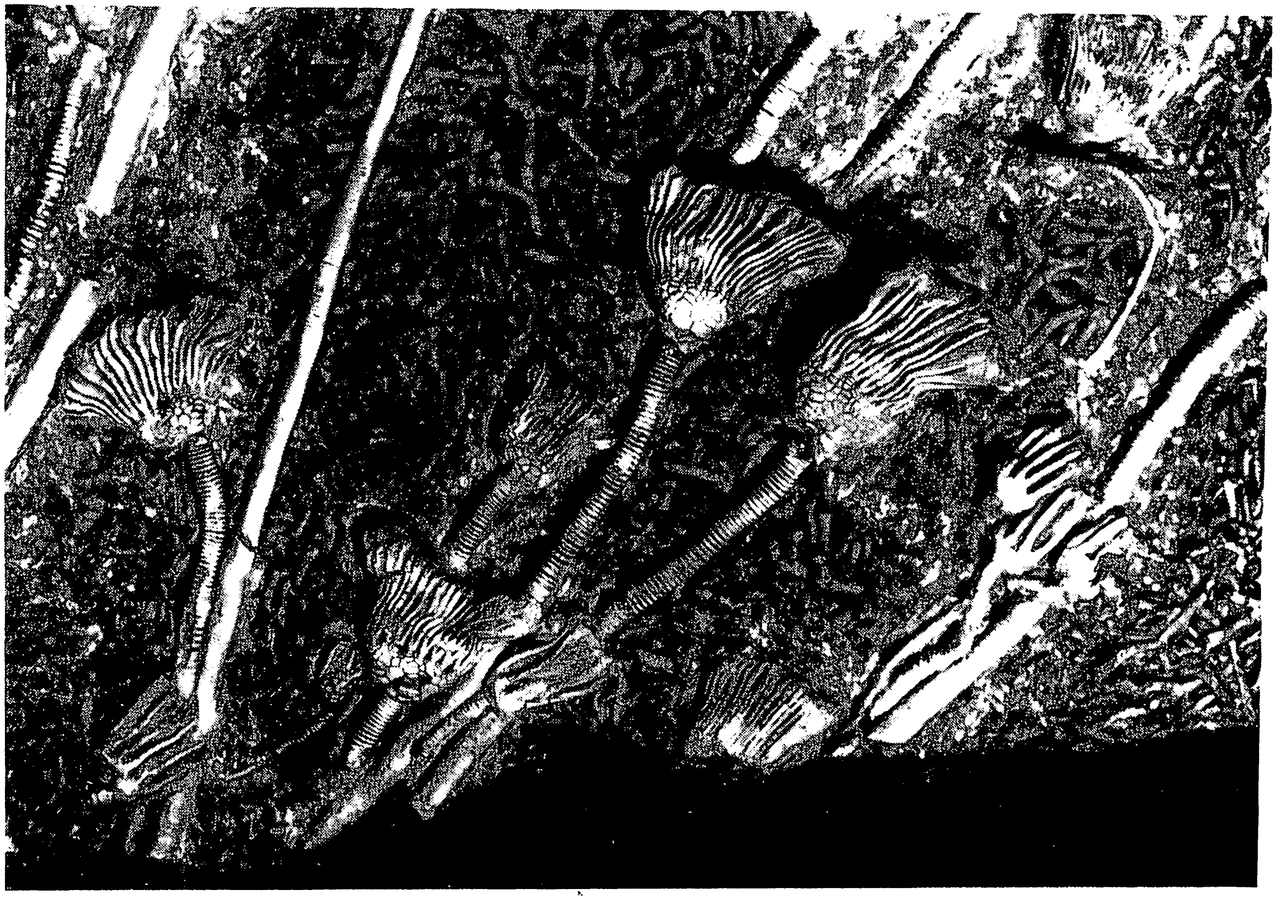
The persons who wrote this article had the great opportunity to find, summer - 1990, a very good conditioned example of one crown of a chrinoid with treca and arms with pinnule, in the same area where the Nar - plate was found. At the same place, we also found some very fine root -fragments.

On the whole, Gotland is one of the worlds most prolific places when looking for chrinoids.

ACKNOWLEDGEMENT:
The authors wish to convey their gratitude to Christina Frazen-Bengtson of the Swedish Museum of Natural History, who furnished the photographs and identified the crinoids on the Nar-plate.



NAR - PLATE: DESMIDOCRINUS PENTADACTYLUS
(in parts)

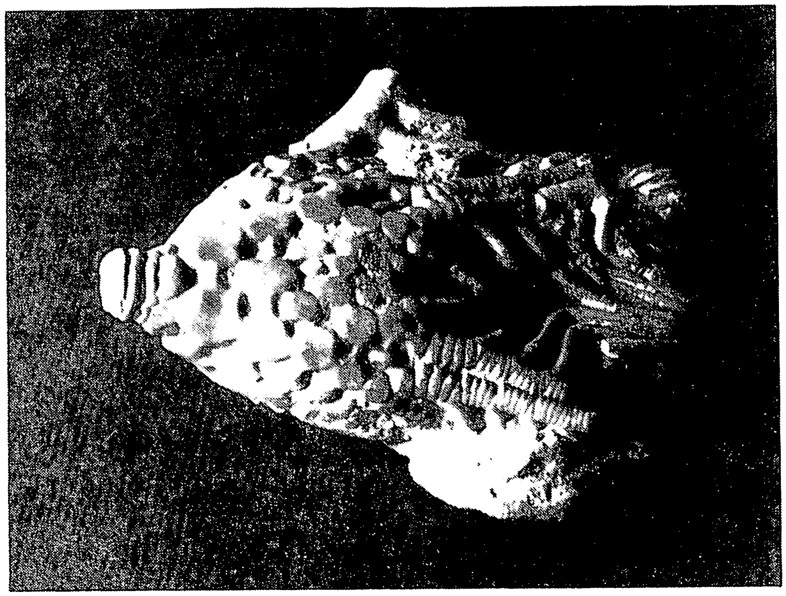


NAR - PLATE (part)

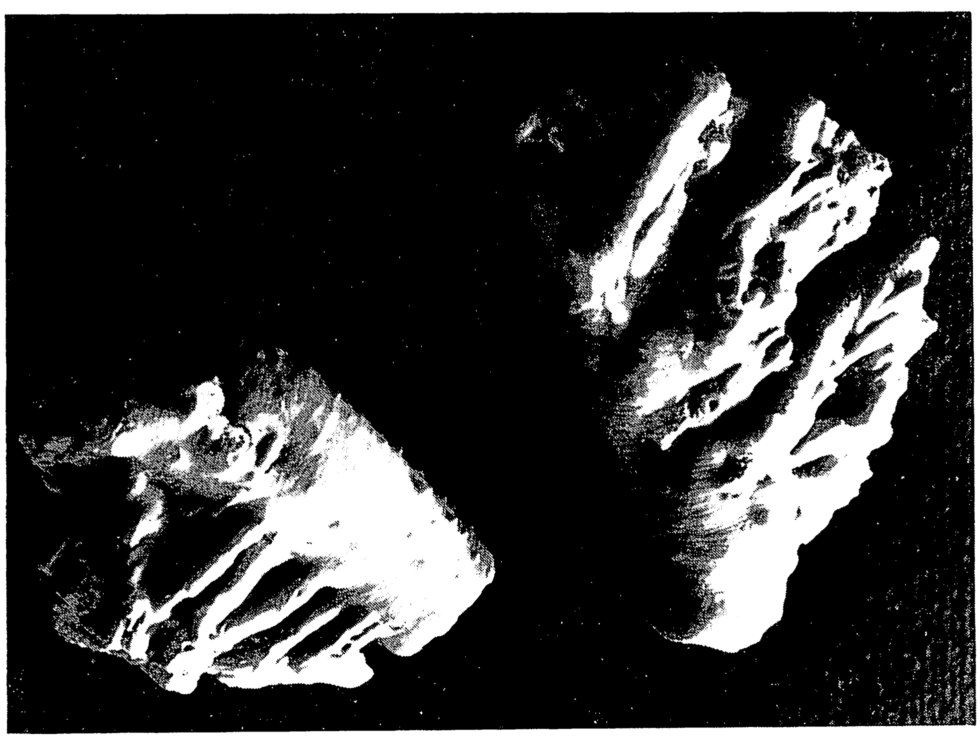
(99 cm)

CARPOCRINUS PETILUS

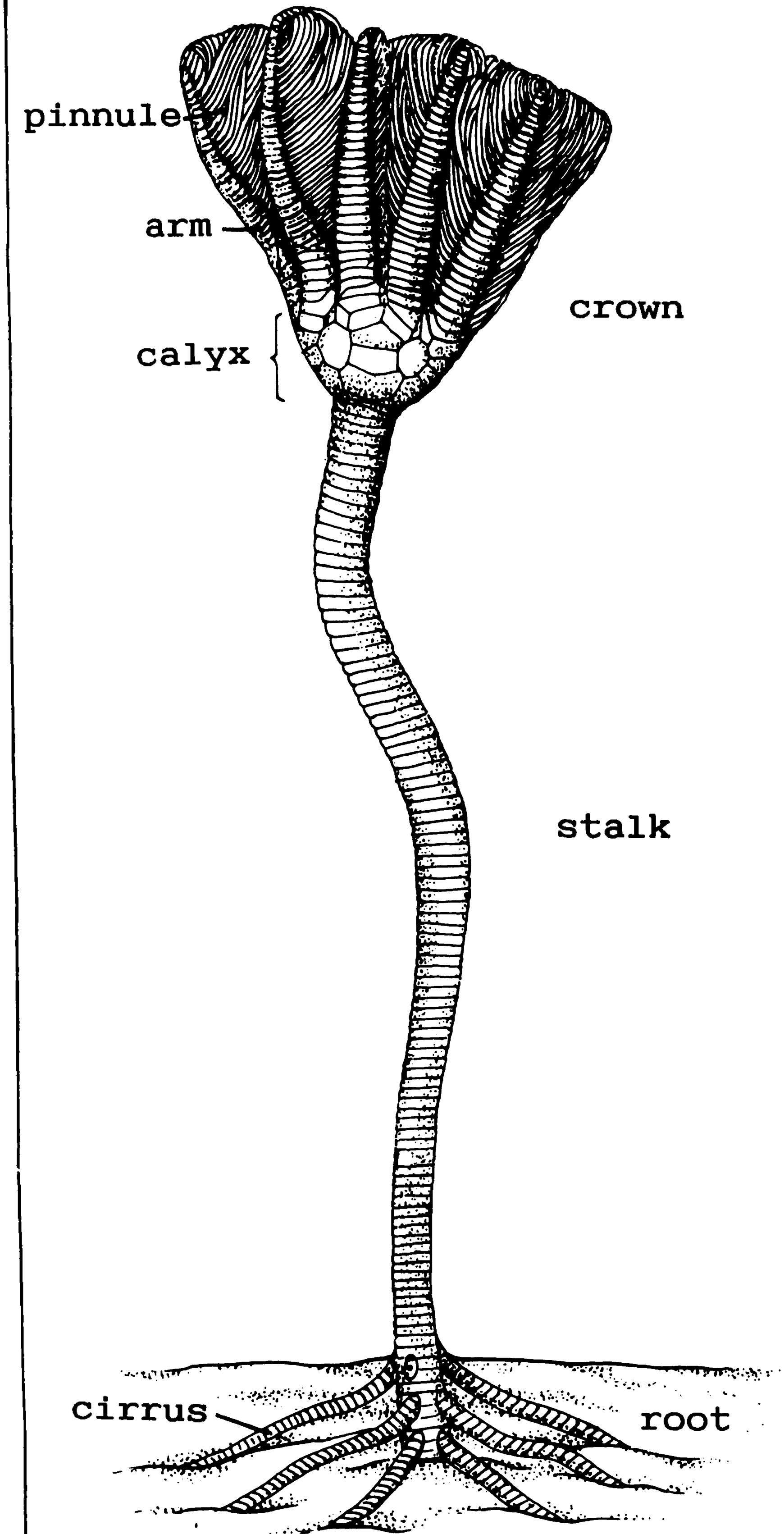
CARPOCRINUS SIMPLEX (Phillips)
(Editor's identification)



MELOCRINUS SP.
(Editor's identification)



CRINOID ROOT


pinnule
arm
crown
calyx
stalk
cirrus
root

GOTLANDSKA FOSSILS

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The island of Gotland, a province of Sweden, is located about 50 miles off the mainland in the Baltic Sea between Sweden and Latvia and covers an area of about 110 miles by 30 miles. Fossils can be found anywhere on the island which is home for 50,000 people and has an influx of an additional 400,000 vacationers in the summer. It is one of the best Silurian deposits in the world, covering the Wenlock and Ludlow series plus a small portion of the Llandovery. This is equivalent to the Niagarian and Cayugan series in the United States. These series extend under the sea to Estonia on the east.

The oldest rocks on Gotland are on the northwest coast. The cliffs are composed of the lower Visby marl, upper Visby marl and Hogklint limestone.

The original fossil work was done at Vattenfallet (Visby) by G. Lindstrum in 1861. Lindstrum then found a 16" eurypterid zone when the Geological Survey of Sweden designated this the type section and hired G. Lijevall to systematically study the area in 1908. The zone has since been built over. This section covers the lower Wenlock series. It was named for the area in England where the original research on the Silurian was done. This covers about half the fossils on Gotland. The fossils described in the literature covers the entire animal kingdom. The common fossils found are brachiopods, mollusks, and corals.

Visby, the principal city, was founded in the middle ages and was a member of the Hanseatic League. (Old High German is very close to the Old Gotland language). The Visby city wall is still standing and the "old city" has become a tourist attraction with the modern city and markets built outside the wall. This wall was put up to keep the farmers out, not to protect the city from foreign intruders. Gotland became part of Sweden in 1720.

The northeast thumb of the island is a Swedish military zone where only Swedes may get off the roads and visit the beach and cliff areas. The army maneuvering area near Visby is open to anyone when the army is not in training. They just leave the gate open when its ok to enter.

The Bunge Museum in this northeast area has items from the Bronze age through Viking times. Aside from the artifacts, reconstructed buildings etc., there are many other sites of interest; such as numerous "stone ships", (the outline of ships made of huge placed rocks), part of the ancients rites of passage from this world to eternity. There are churches of the middle ages throughout the area. It is a tourist mecca with the numerous restaurants and motels. Room and mini-apartments are also provided in the homes of many local folk during the tourist season.

We were lucky and met several local collectors who showed us where to hunt. The beaches are public property, but I would not advise collecting when its wall to wall people in the summer. The spring is best for collecting because you have the advantage of the tides, waves and rains working through the winter, to give you a fresh look.

Speaking of beaches... sponges similar to those found in Tennessee are found only with the tide deposits from off the shore beds. They are valued by the local collectors as high or higher than trilobites.

The same formation is found on the coastline from south of Visby to the northwest cliffs at Hallshuk. Among the many corals we found the rare square opening Hoglint limestone Goniophyllum pyramidalle. (two loose in the tallus). Occasionally you can see one in the cliffs south of Visby. I can only describe this land by saying it must have been as rich in corals as the Great Barrier Reef of Aistralia is today. All the Hallshuk corals were found in the under Visby marl.

Next we went to Grogarnsberget on the east coast in the Klinteberg group. This was a cephalopod collectors dream with nearly matrix- free (limestone) specimens in the surf. Also here I found a bed of Gypidula in shale at the tide line. Of course many corals were here, some different from the northwest cliffs as this is in the Ludlow series.

Probably the most diversified collecting horizon is the Hemse Shale (south) deposit similar in color to the Waldron shale, but harder so it does not dissolve in the rain. Large areas are exposed as a canal was dug through the land some 10 years ago.

We were taken to a farm that had recently extracted large amounts of blue shale to create ponds for the purpose of raising crabs for the food markets. This blue shale is best collected after rains wash the surfaces. It had been collected extensively the week before we were there by local collectors so we found only trilobite parts. Several complete Calymene had been found. This had been brachiopod heaven and the large Meristina are common.

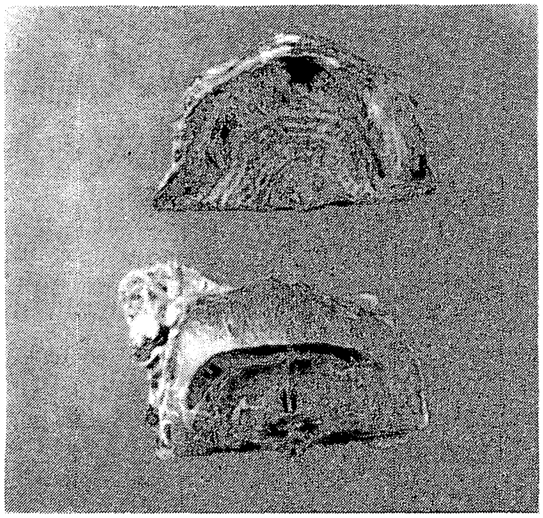
We were shown several large Calymene that had been plowed up by the farmers over the years.

On the east coast near Vratergarn, again at a beach, Cyrtia were coming up through the sand.

The last area checked was the Burgsvik sandstone which has a bivalve deposit. These were coming out of a cliff but the only collecting was from stone walls and a large block that fell from the cliff.

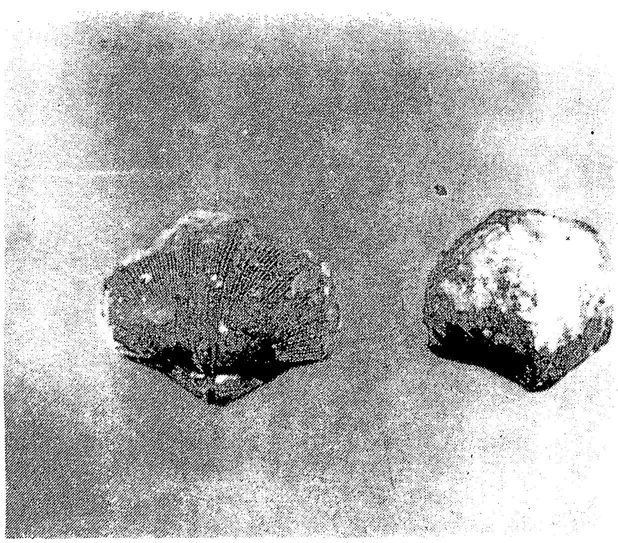
Fossils are found all over the island. I found Conularia in a field ditch near Burs.

In summation, this is the best Silurian collecting areas in the world and surely qualifies as a LAGERSTATTEN.

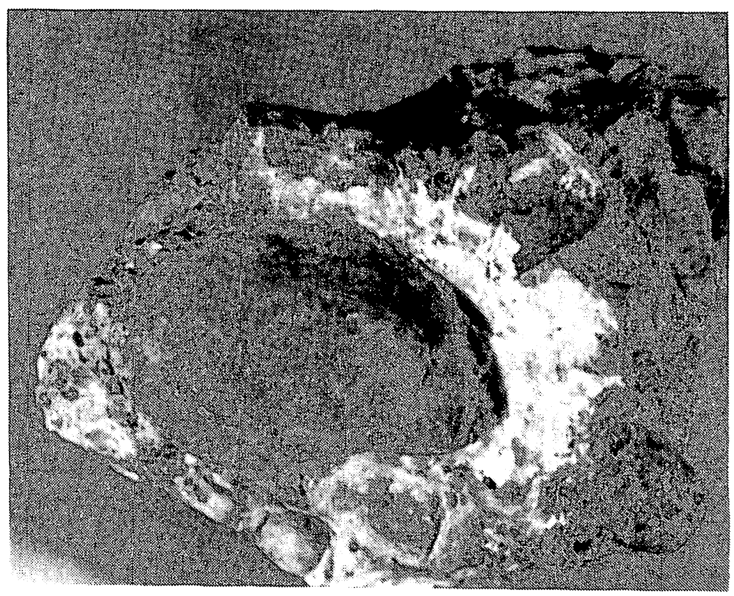


LEPTAENA

CYRTIA

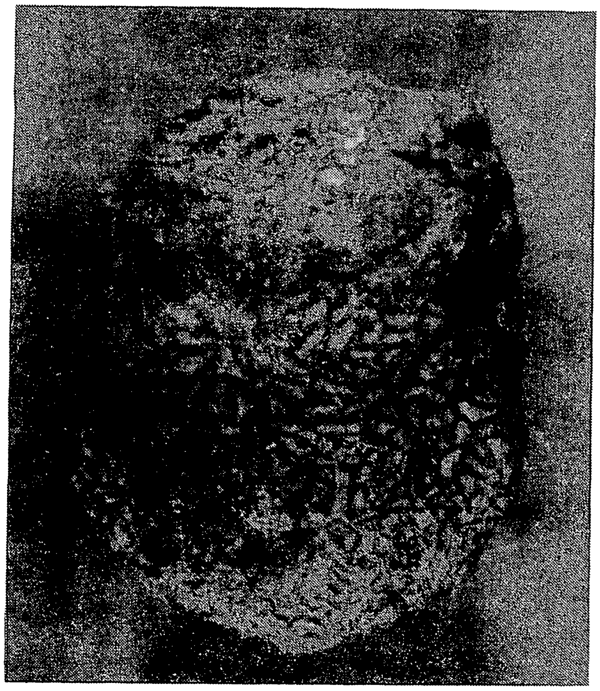


EOSPIRIFER



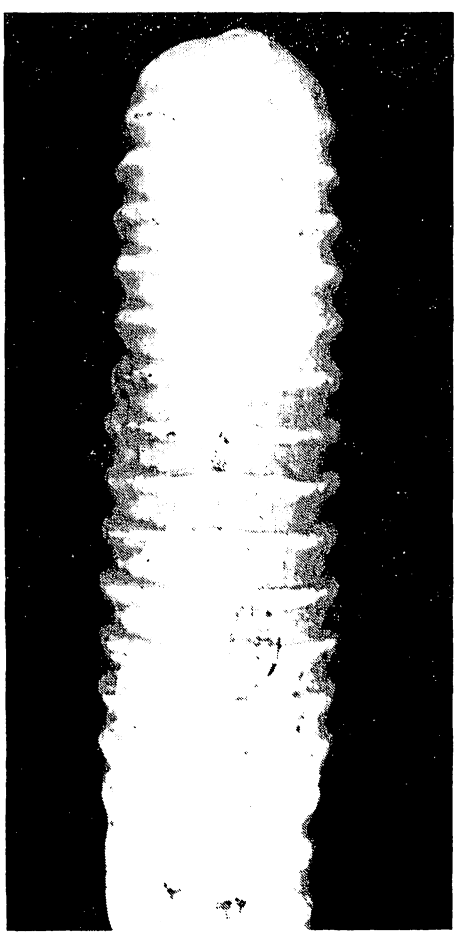
GRAMMYSIA

FOSSILS x1



HALYSITES CATENULARIA x1

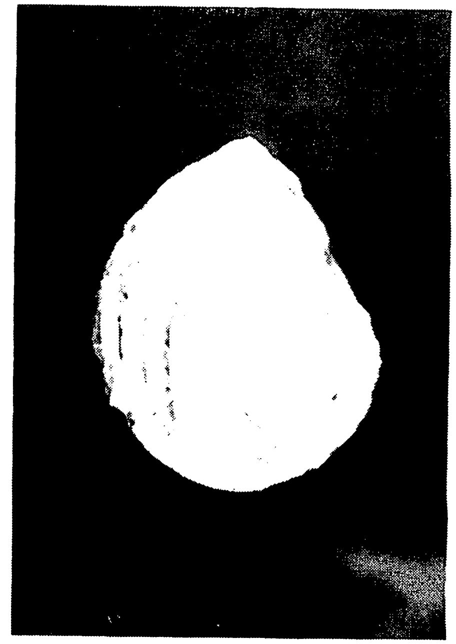
GONIOPHYLLUM PYRAMIDALE x1



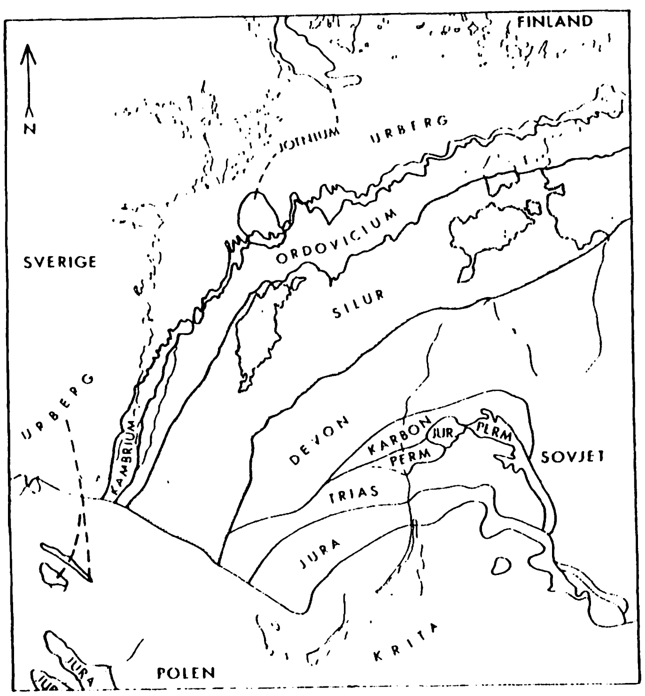
DAWSONOCERAS x1

ORTHOCERAS x1

NAUTILOID EXTERNAL SHELL DETAIL
x 1

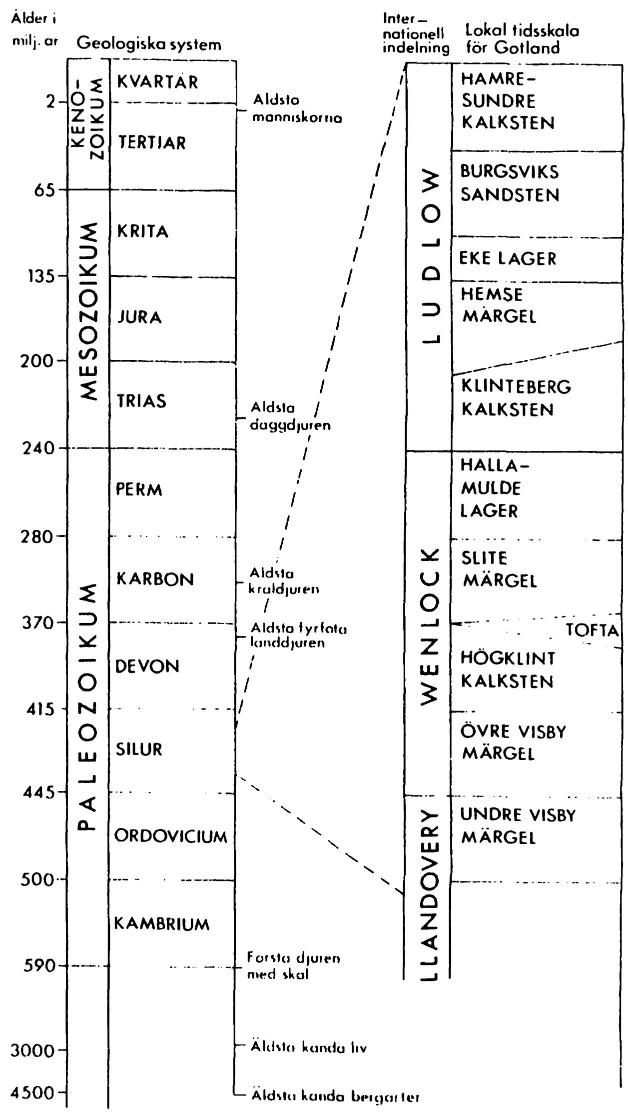


ORIOSTOMA x1



Berggrundsgeologisk karta över Östersjöområdet. Förenklad efter T. Flodén.

Den geologiska tidsskalan.



Time chart: efter Brood → 56

LAGERSTATTEN: ENVIRONMENT AND FOSSIL FAUNA

OF THE LATE CRETACEOUS NIOBRARA FORMATION

CENTRAL PLAIN STATES

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The word Cretaceous is formed from the Latin word for chalk, Greta. The name of this geologic period, which began about 125 million years ago and ended about 65 million years ago, was first applied to chalk beds which form the bedrock of the southeastern part of England and which are conspicuously exposed on the shore of the English Channel.

Chalk is formed of an accumulation of microscopic particles called coccoliths, which are the hard parts of floating protozoa. Chalk beds, formed of about seven million years accumulation of these calcium carbonate particles at about the same time as those of southeastern England, are widespread in Kansas, Nebraska, South Dakota, and eastern parts of Colorado and Wyoming. The first geologists to travel up the Missouri River, F. B. Meek and F. V. Hayden, named the chalk formation for the Niobrara River, whose mouth is on the Missouri about midway between Fort Randall and Yankton, South Dakota. These geologists went up the Missouri about the time of the Civil War. Outcrops of the chalk formation, of an orange-yellow color, are conspicuous near the mouth of the Niobrara River. The fossil fauna of the Niobrara chalk first got national attention a few years after the Civil War. Prof. Edward D. Cope, of Philadelphia, hired Charles Sternberg, a college youth, to collect marine vertebrates from the chalk in the west-central part of Kansas.

There is very little mud or sand in the Niobrara chalk, which indicates that the nearest shore was over 150 miles from any part of the area of deposition. For reasons not perfectly understood, but probably due to plate movements, most of the region of the present Great Plains and Rocky Mountains was below sea level during the latter half of the Cretaceous period. The dark-gray-to-yellow chalk which accumulated in the middle of this western interior sea is the Niobrara formation. At the time of greatest intrusion or transgression of the sea, the Gulf of Mexico extended north through Canada and divided the continent.

At the beginning of Niobrara deposition, the water was shallow enough to allow sunlight and free oxygen to reach the bottom.

These conditions allowed many kinds of invertebrates to live on the bottom and eat the organic remains which sank from above, e.g. dead bodies and excreta of vertebrates which lived near the surface. Bottom-dwelling invertebrates burrowed through the marly sea floor while searching for food. As a result, the older, lower part of the chalk, the Fort Hays member, is churned or "bioturbated" and shows no bedding planes. Few fossils of vertebrates or invertebrates can be found in it.

In contrast to the shallow "Fort Hays"sea whose bottom swarmed with active invertebrate life, the bottom of the later "Smoky Hill" sea subsided to a depth of about 600 feet a depth at which little oxygen or sunlight entered the environment. At that depth, bottom-dwelling invertebrate life was limited to a small variety of clam and oyster forms So, vertebrate remains which sank to the bottom were more likely to be preserved complete and articulated. The warm water near the surface swarmed with a great variety of fishes and the large swimming reptiles which preyed on them.

The most abundant marine reptile family was the mosasaurs. In body form, they mostly resembled walruses or sea lions with crocodile's heads and tails. It is believed that the most likely ancestors of mosasaurus was a land dwelling varanid lizard. The best-known examples of varanid lizards, and likely the mosasaurus' closest living relatives, are the "dragon lizards" which inhabit some islands between Timor and Java in Indonesia.

Mosasaurs' length ranged from 12 to 32 feet. Their prey was every kind of animal in the sea that they could reach. Stomach contents of a mosasaur, on display at the South Dakota School of Mines Museum in Rapid City, include a shark, another mosasaur, and a bird, crammed and jumbled together. Mosasausus' jaw were hinged near the middle so that the wider the jaw opened, the broader it gaped. This arrangement made it possible for the reptile to swallow whole prey almost as large in girth as itself, as in the case with some modern lizards and snakes.

Plesiosaurs, of another order of aquatic reptiles, first became numerous in the Early Jurassic and had just begun to decline in numbers by the time of Niobrara deposition. The squat body with broad flippers resembled a walrus. Some had short necks and long heads. The most famous late Cretaceous form had a neck which was about as long as the torso and had a snake-like head. If the neck was flexible and agile, this plesiosaur could have preyed on fish in the manner of a snake striking.

Pterosaurs, "winged reptiles", were numerous over the interior sea. Resembling super-size pelicans or albatrosses, they swooped low over the water to snap up fish near the surface. Likely they nested in near-shore cliffs, and returned to disgorge partly digested fish for their young in the nests. Fossils found recently in Texas indicate that the wingspread of the largest pterosaurs may have exceded 40 feet. They were well-equipped to soar and glide and could travel long distances from the shore.

Aquatic birds were numerous on and over the Niorbara Sea. Most abundant were the Ichthyornis, resembling a gull, and Hesperornis, a flightless bird that dived for its prey in the manner of a cormorant or a loon. Likely both of these birds gorged on fish, and both had teeth in their lower jaws to grip squirming, slippery prey.

At the time of Niobrara chalk deposition, the interior sea was about 800 miles wide in the neighborhood of Kansas, Nebraska and South Dakota. The sea completely divided the continent for a time. "West America" was a narrow, mountainous island, several thousand miles long, from Mexico northwestward to a probable connection to Siberia and central Asia. Its eastern flanks were alluvial piedmont, the home of a dinosaur fauna mostly of herbivorous ornithischians and the tyrannosaurids and other biped carivores which preyed on them. Accompanying these dinosaurs was a variety of reptiles suited to warm-temperate-to-subtropical habitat, and an increasing number of tiny marsupial and placental mammals.

"East America" likely was home to most of the same forms of animal life. It was a maturely-eroded land of low relief in most places. The stubs of late Paleozoic folded mountains in Missouri, Arkansas and Oklahoma may have formed good-sized ranges of hills near the eastern shore of the interior sea. Granite, quartzite and gneiss, the remnants of a strongly metamorphosed pre-Cambrian range in eastern South Dakota and west-central Minnesota, may have formed a rocky, California-like coastline and extended as chains of islands out to sea. Warm, shallow bays around these rocky coasts and islands were home to schools of fish, and to the sharks and swimming reptiles which feasted on them.

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A FOSSIL SITE NEAR SULPHUR, INDIANA (CHESTERIAN, MISSISSIPPIAN)

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Some Terminology

The terms Konservat-Lagerstätten or Lagerstätten do not appear in Bates and Jackson (1987) and both terms have been transferred directly into English from the German paleontological literature. Seilacher (1970) did not comment on the origin of the term Fossil-Lagerstätten until he co-authored a subsequent review (Seilacher, Reif, and Westphal, 1985). Lagerstätten means literally resting-place and apparently appeared first as a technical word in the German mining literature where the term was associated with ore deposits (Heubner, 1939). Ores are economic deposits, that is, valuable commercial concentrations of a substance. Hence, Konservat-Lagerstätten are considered valuable sources of paleontologic information as the result of special conditions of preservation. In English the term "mother-lode" is used colloquially in a similar sense.

In the site discussed below, the finest preservation of fossils occurs at the tops of beds of limestone covered by shales. Shrock (1948, p. 307-310) referred to these types of occurrences as smothered bottoms. Although smothered bottoms are among the commonest of Konservat-Lagerstätten, they were apparently considered principally as enhancing reducing conditions of preservation in the sub-categories of Konservat-Lagerstätten originally defined by Seilacher (1970). Subsequently, Seilacher, Reif, and Westphal (1985) gave more attention to the physical conditions of the rapid burial (their term: obrution) sub-category of Konservat-Lagerstätten, which includes smothered bottoms. The most notable occurrences at this site are of echinoderms, especially crinoids and blastoids that exhibit entire crowns and extensive lengths of stem.

The Sulphur Site

An extensive exposure of Late Mississippian (early and middle Chesterian) rocks (Figure 1 and Table 1) is located at the junction of Interstate 64 and Indiana Highway 37 approximately 1 mile (1.5 km) north of Sulphur, Crawford County, Indiana on the Beechwood U. S. Geological Survey 7.5-minute topographic quadrangle (Horowitz and Kelly, 1987). The Reelsville-Elwren interval is best exposed on the southeast access ramp of the highway junction. The most extensive exposures are on the northeast corner of the highway junction

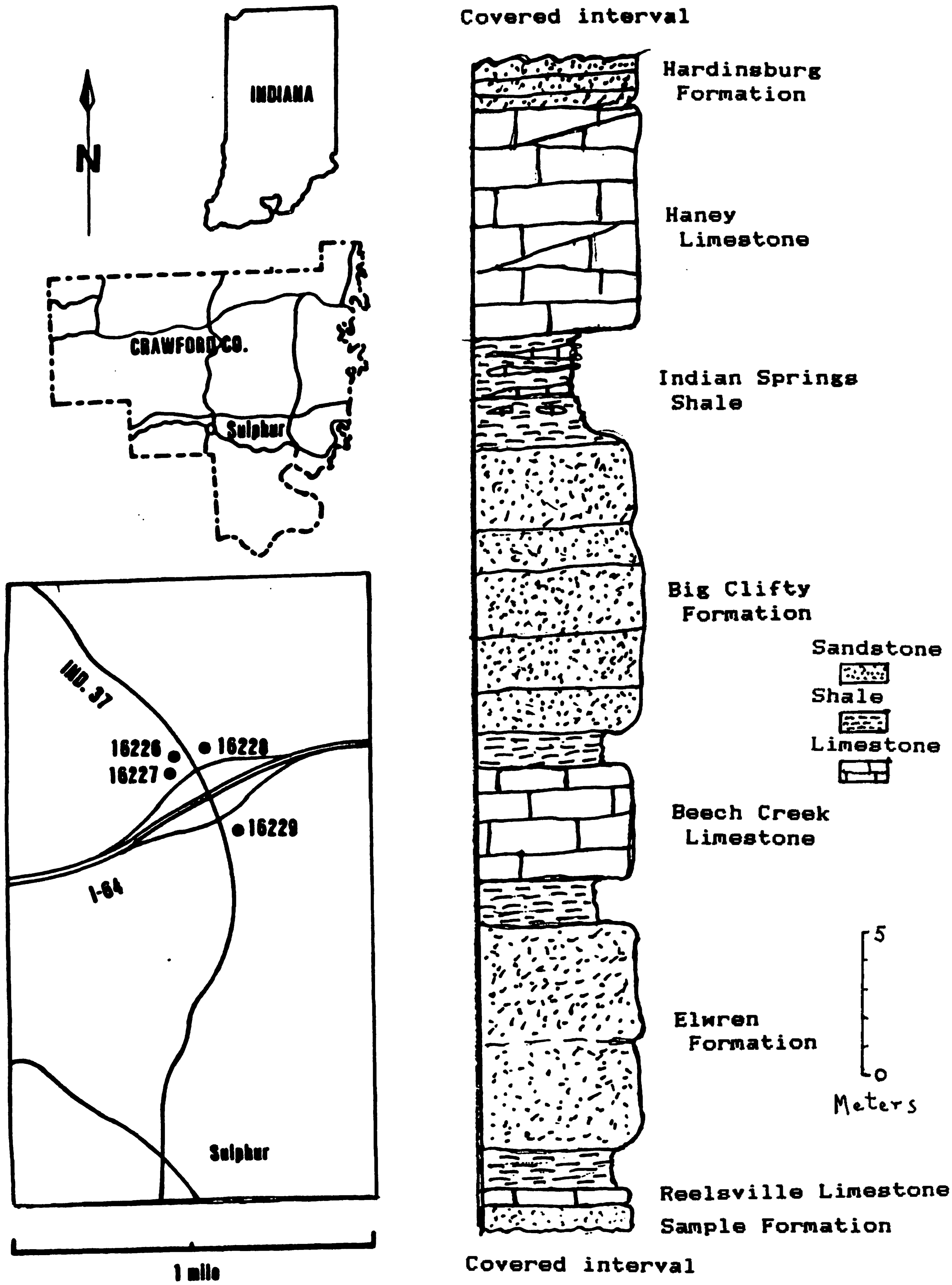

Figure 1. Geographic position (from Kelly, 1984) and graphic stratigraphic section of Sulphur site.

Table 1. Formations occurring in the roadcuts at the junction of Interstate Highway 64 and Indiana Highway 37.

Hardinsburg Formation
Haney Limestone
Indian Springs Shale (=Fraileys Shale)
Big Clifty Formation
Beech Creek Limestone
Elwren Sandstone (=Cypress Sandstone)
Reelsville Limestone
Sample Formation

approximately N1/2 S1/2 Sec. 24, T. 3 S., R. 1 W., which reveal at road level varicolored shales at the top of the Elwren Sandstone and the overlying Beech Creek Limestone. Highway construction has produced a series of benchs of which the highest is several meters wide and occurs within or at the top of the Indian Springs Shale. Excavations covering several square meters have been made along this bench by amateur and professional fossil collectors.

These exposures have been the focus of several theses at Indiana University and the work reported in the earliest theses was briefly summarized by Horowitz and Kelly (1987). The present discussion will be directed to the richly fossiliferous Indian Springs Shale (Kelly, 1984) that lies between the Big Clifty Formation below (Suttner and Visher, 1979; Visher, 1980a,b) and the Haney Limestone above (Foster, 1990). Most of the information presented below is based on the work of Kelly (1984).

In this area, the Indian Springs Shale is between 3 and 4 meters (10-13 feet) thick and consists of a predominantly shale lower interval and an interbedded limestone and shale upper interval. The lower shale interval is not very fossiliferous except near its top where a low diversity ostracode and molluscan (mostly pelecypod) fauna has been recovered. The source of the best preserved specimens is the richly fossiliferous upper interval of interbedded limestone and shale. Limestone beds in the Indian Springs range from feather edges up to 30 cm (1 foot) thick and are composed almost exclusively of fragmental calcareous skeletal debris of brachiopods, bryozoans, and echinoderms. These three groups were the dominant contributors to carbonate sands and coarser debris in the warm shallow seas that covered southern Indiana during late Mississippian time. Paleogeographic reconstructions indicate that southeastern Indiana was 5 to 10 degrees south of the equator at this time.

Diversity (also called disparity in Gould, 1989) of the fossils differs greatly between the two intervals within the Indian Springs Shale (Table 2). The entire unit contains

Table 2. Generic diversity for major groups of fossils within lower and upper intervals of the Indian Springs Shale. Data compiled from Kelly (1984). X=present.

	Lower Shale	Upper Shale and Limestone
Coelenterata	-	2
Echinodermata	1	26
Bryozoa	2	15
Brachiopoda	6	16
Mollusca	5	9
Arthropoda	6	10
Worm tubes	X	1
Vertebrata	X	18

nearly 100 genera of fossils. This is a minimun number because some groups have not received adequate taxonomic study.

Kelly (1984) interpreted both the individual life habits of the shelly fauna and the associations of species within the Indian Springs Shale (Table 3 from Kelly, 1984; Horowitz and Kelly, 1987). The dominant elements of the shelly fauna are the filter-feeding echinoderms, bryozoans, and brachiopods. Most of these forms are interpreted as living attached to the sea-floor (sessile benthos), but the stems of crinoids and blastoids may have functioned as grappling hooks so that they had some potential for being moved by currents and reattaching to the bottom if conditions changed.

The organisms living in the Indian Springs seas lived at various heights above the sea floor (Table 3). Low level feeders encrusted the bottom or they fed in approximately the lower 15 cm (6 inches) of the water column. Feeders at the intermediate level were elevated approximately 15-50 cm (6-20 inches) above the bottom and feeders at the highest level were more than 50 cm (20 inches) above the bottom. Feeding strategies were divided into suspension (typically filter) feeders, detritus feeders, and predators (Table 3). Clearly the most common groups of fossils fed on the smallest sizes of food (microphagous) found in the waters during deposition of the Indian Springs Formation. See Table 4 for a list of the fauna from this site.

Conway Morris (1979) indicated that the sessile benthos in the famous Middle Cambrian Burgess Shale probably fed from the bottom up to perhaps 20 cm above the bottom. Long before the Mississippian, sessile invertebrates had begun feeding higher and higher into the water column. Crinoid stems a meter or more long are known in mid and late Paleozoic shallow continental seas (Ausich and Bottjer, 1985).

Table 3. Summary of feeding strategies of fossils found in the Indian Springs Shale, near Sulphur, Indiana. Phestia and Sanguinolites are pelecypods; Spirorbis is a coiled encrusting calcareous worm tube; Tubulelloides is a straight phosphatic worm tube; Archimedes is the coiled (screw) bryozoan; Onychocrinus and Taxocrinus are crinoids.

Feeding Strategy	Suspension feeders: Microphagous	Suspension feeders: Macrophagous	Detritus feeders (browsers & scavengers)	Predators
Low (on or near bottom)	brachiopods, bryozoans Sanguinolites conularid Spirorbis Tubulelloides	cup corals	?scolecodonts, ?ostracods, trilobites, non-platycerid gastropods Phestia	?scolecodonts, ?ostracods cephalopods, vertebrates
Medium	blastoids, Archimedes, fenestrate fronds, short-stemmed crinoids	small Taxocrinus		cephalopods vertebrates
High	long-stemmed crinoids	large Taxocrinus and Onychocrinus		cephalopods vertebrates

Paleontologists are interested in the diversity of life through time. Commonly only forms possessing skeletons are preserved in the fossil record. In this connection, it is interesting to note that the generic diversity (disparity = 116) of the Burgess Shale, including all the soft-bodied forms, is approximately that of the shelled invertebrates in the late Mississippian Indian Springs Shale. Because soft-bodied forms are not known from the Indian Springs Shale or from any Chesterian rocks in the Illinois Basin (principally Illinois, Indiana and Kentucky), the diversity of life during the deposition of the Indian Springs Shale probably was greater than for a comparable site during the Middle Cambrian.

Rapid burial can permit some assessment of the community actually living at the time of burial as contrasted with associations due to current sorting and accumulation. However, detailed studies of individual limestone surfaces have not been recorded for this site, an indication that paleontologic studies are never complete. Additional data always will be needed to assess concepts receiving renewed interest, especially hypotheses testable with higher resolution by improved technology and more detailed collecting. Only a few published papers deal with this Indian Springs site. In addition to those works cited above, Welch (1976, 1978) has published on fossils from this locality.

I thank J. R. Dodd and N. Gary Lane for reviewing an earlier version of this report.

Table 4. Faunal list from Sulphur site compiled from Kelly (1984).

Foraminifera
- ?*Archaediscus* sp.
- ?*Calcivertella* sp.
- ?*Tetrataxis* sp.
- ?*Endothyra* sp.

Coelenterata
- *Zaphrentoides* (*Amplexizaphrentis*) *spinulosum* (Milne-Edwards & Haime)

Worms
- *Paraconularia chesterensis* (Worthen)
- *Spirorbis* sp. (three varieties)
- *Tubulelloides* sp.
- Worm "teeth" (scolecodonts)

Trilobita
- *Paladin chesterensis* (Weller & Weller)

Ostracoda
- *Amphissites* sp.
- *Cavellina* sp.
- *Cornigella golcondensis* (Croneis & Gale)
- *Geisina* sp.
- *Hypotetragona* sp.
- *Kirkbya* sp.
- *Polytylites biforatus* (Croneis & Thurman)
- *Polytylites quincollinus* (Harlton)
- *Polytylites suprus* (Croneis & Gale)

Brachiopoda
- *Anthracospirifer leidyi* (Norwood & Pratten)
- *Beecheria* sp.
- *Cleiothyridina sublamellosa* (Hall)
- *Composita trinuclea* (Hall)
- *Crania* sp. cf. *C. chesterensis* Miller & Gurley
- *Diaphragmus* sp.
- *Echinoconchus alternatus* (Norwood & Pratten)
- *Eumetria* sp.

Table 4 (continued)

Brachiopoda (continued)
- *Lingula* sp.
- *Orbiculoidea* sp.
- *Orthotetes* sp.
- *Ovatia* sp. cf. *O. ovata* (Hall)
- *Punctospirifer transversus* (McChesney)
- *Reticulariina spinosa* (Norwood & Pratten)
- *Schuchertella* sp.
- *Trigonoglossa* sp.

Bryozoa
- *Archimedes* sp.
- *Ascopora* sp. (two forms)
- *Callocladia* sp.
- *Cheilotrypa* sp.
- *Eridopora* sp.
- *Fenestella* sp.
- *Fistulipora* sp.
- *Hederella* sp.
- *Lyroporella* sp.
- *Meekopora* sp.
- *Polypora* sp.
- *Rhabdomeson* sp.
- *Septopora* sp.
- *Tabulipora* sp.
- *Thamniscus* sp.

Gastropoda
- bellerophontacean sp.
- *Borestus* sp.
- ?*Bulimorpha* sp.
- ?*Donaldina* sp.
- ?*Meekospira* sp.
- ?*Naticopsis* sp.
- *Orthonychia chesterense* (Meek & Worthen)
- ?*Stegocoelia* sp.

Cephalopoda
- *Stroboceras* (*Epistroboceras*) sp. cf. *S.* (*E.*) *texanum* (Miller & Youngquist)
- *Stroboceras* (*Stroboceras*) sp. cf. *S.* (*S.*) *cripsum* Gordon
- *Triptoceroides knighti* Miller & Furnish

Bivalvia (Pelecypoda)
- ?*Aviculopecten* sp.
- *Nuculopsis* sp.
- ?*Permophorus* sp.
- ?*Phestia* sp.
- *Sanguinolites* sp.

Echinodermata
- *Acrocrinus* cf. *A. constrictus* Burdick & Strimple

Table 4 (continued)

Echinodermata (continued)
- *Allagecrinus* sp.
- *Agassizocrinus* sp.
- *Aphelecrinus oweni* Kirk
- *Archaeocidaris* sp.
- *Camptocrinus* cf. *C. multicirrus* Springer
- *Culmicrinus* sp.
- *Cymbiocrinus* sp.
- *Dichocrinus* sp.
- *Diploblastus* sp.
- *Harmostocrinus* cf. *H. minuspiniferous* Strimple
- *Hyrtanecrinus inflatus* Broadhead & Strimple
- *Hyrtanecrinus pentalobus* (Casseday & Lyon)
- *Lepidesthus* sp.
- *Lepidodiscus* sp.
- *Neopalaester* sp.
- *Onychocrinus pulaskiensis* Miller & Gurley
- *Passalocrinus* sp.
- *Pentaramicrinus bimagnaramus* Burdick & Strimple
- *Pentremites* sp. (at least 4 forms)
- *Phanocrinus* sp.
- *Phacelocrinus longidactylus* (McChesney)
- *Pterotocrinus rugosus* Lyon & Casseday
- *Ramulocrinus milleri* (Wetherby)
- *Taxocrinus* cf. *T. whitfiledi* (Hall)
- *Tholocrinus discus* Strimple
- *Tholocrinus* cf. *T. spinosus* (Wood)
- *Tremataster* sp.
- *Zeacrinites* cf. *Z. wortheni* (Hall)

Taxa of Unknown Affinities
- *Cornulites* sp. (conical encrusting tube)
- *Phosphanulus* sp. (phosphatic crinoid stem infestor)
- *Turrilepas* sp. (machaeridian)

Vertebrata
- Acanthodian spines
- Actinopterygian scales
- *Ctenopetalus* sp.
- *Chomatodus* sp.
- *Cladodus* sp. (three forms)
- *Deltodus* sp. (two forms)
- *Deltaptychius* sp.
- *Fissodus* sp.
- *Helodus* sp.
- ?*Lissodus* sp.
- *Lophodus* sp.
- ?*Orodus* sp.
- *Petalodus* sp.
- *Platyxetrodus* sp.
- *Pleurodus* sp. (two forms)
- ?*Poecilodus* sp.

Table 4 (continued)

Vertebrata (continued)
- *Protacrodus* sp.
- *Psammodus* sp.
- *Psephodus* sp.
- *Pterodus* sp.
- rhizodontid sp.
- *Sandalodus* sp.
- *Tanaeodus* sp.

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CAMBRIAN LAGERSTATTEN OF UTAH

by

Lloyd F. and Val G. Gunther
Brigham City, Utah

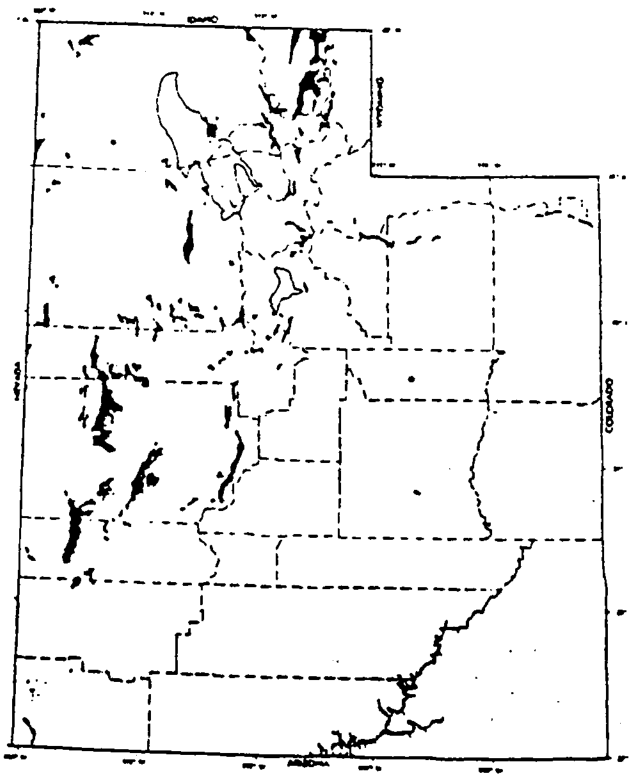
The Cambrian period began approximately 570 million years ago and lasted nearly 75 million years. It is the oldest and longest of the Paleozoic period. Utah has one of the most complete records (exposed outcrops) with abundant and diversified fossil assemblages. Approximately 80 Cambrian formations are recognized.

During the Early Cambrian, sluggish river systems flowing westward across wide sandy flats characterized eastern Utah while western Utah received shallow-water deposits of silt and sand. As the continent continued to subside, the shoreline shifted gradually eastward and the western ocean became progressively deeper. As a result Cambrian sediments thicken westward. By the close of the Middle Cambrian, about 525 million years ago, the shoreline had almost reached the Utah-Colorado border.

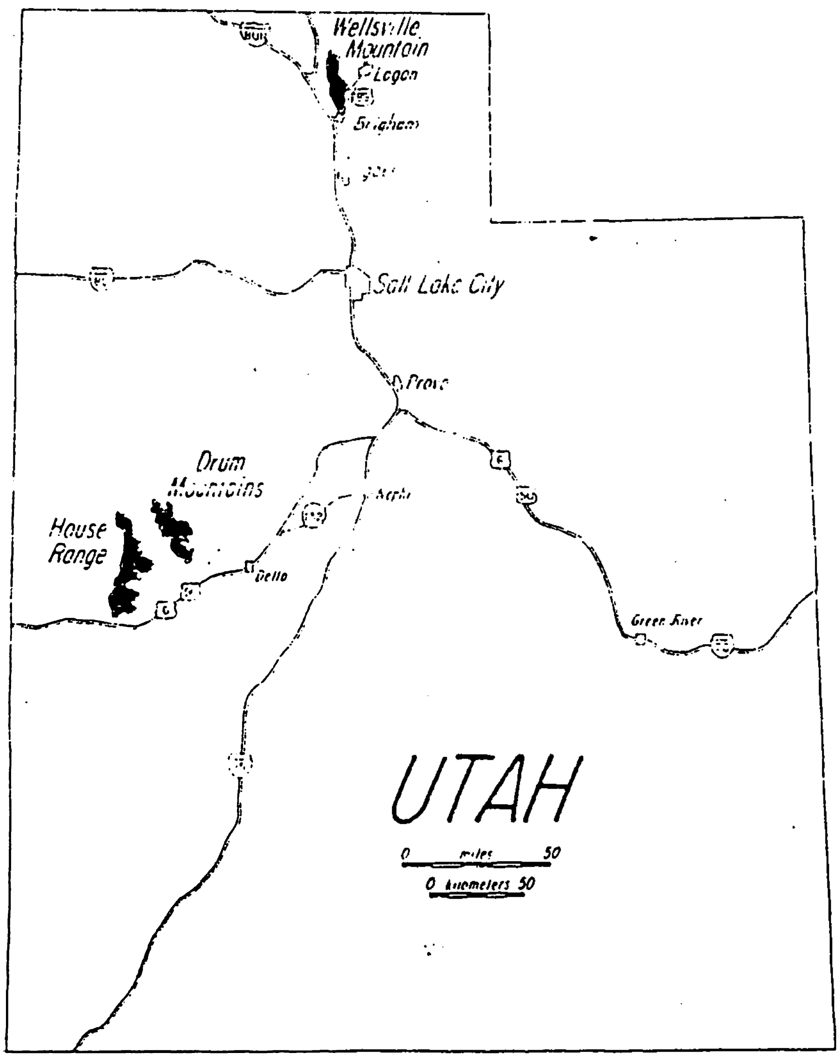
Cambrian sediments were deposited across the entire state and were subject to erosion during all subsequent periods, especially following mountain building. At least half of the original volume of Cambrian rock has been removed by erosion. The most complete outcrops that remain today are found in areas where the original deposits were thickest and most complete.

All evidence paints a picture of Utah in Cambrian time as being vastly different from what it is at present. In Early and Middle Cambrian times the shoreline migrated eastward from Nevada into central Utah. By Late Cambrian marine waters covered nearly the entire state. No mountains of significance were present. Studies suggest the equator ran northward through Utah. It was under these warm water tropical conditions that deposition of limy muds kept pace with subsidence so water depths were never great.

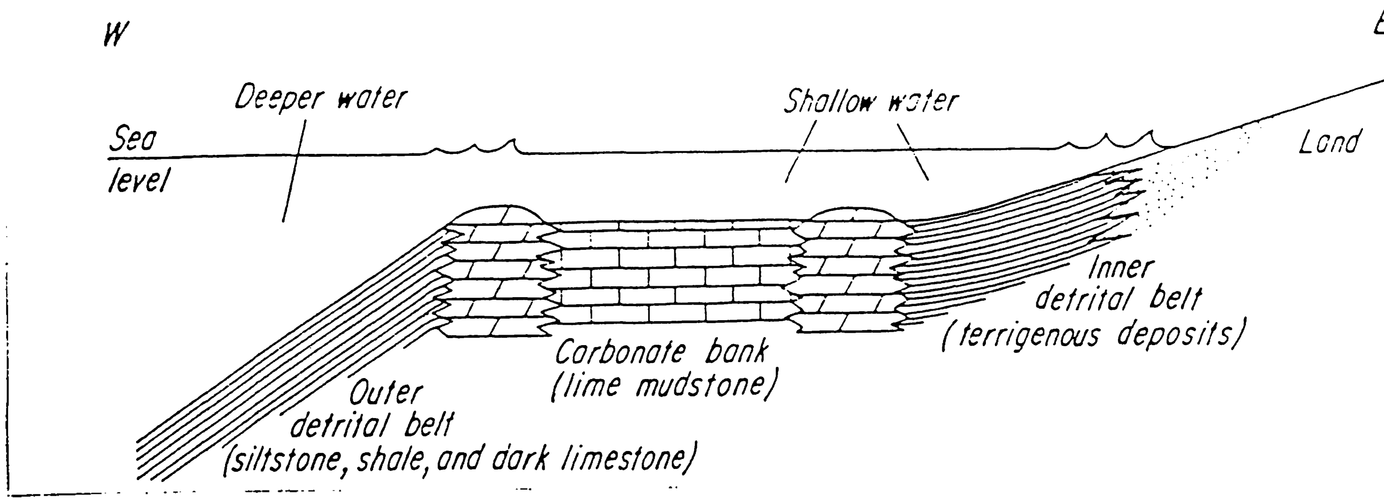
Perhaps foremost of the diverse biotas of Cambrian lagerstatten is the world famous Burgess Shale in the Stephen Formation of British Columbia. Although less spectacular, the term lagerstatten can deservedly be applied to the Spence, Wheeler, and Marjum formations of Utah. The Utah localities have rich biotic diversity that are broadly similar to that of the Burgess Shale and are important in demonstrating that the Burgess specimens are most unique in the excellent state of preservation and not in taxonomic composition.



Outcrops of Cambrian rocks in Utah. Note the wide distribution and closely spaced exposures in the northern and western parts of the State.



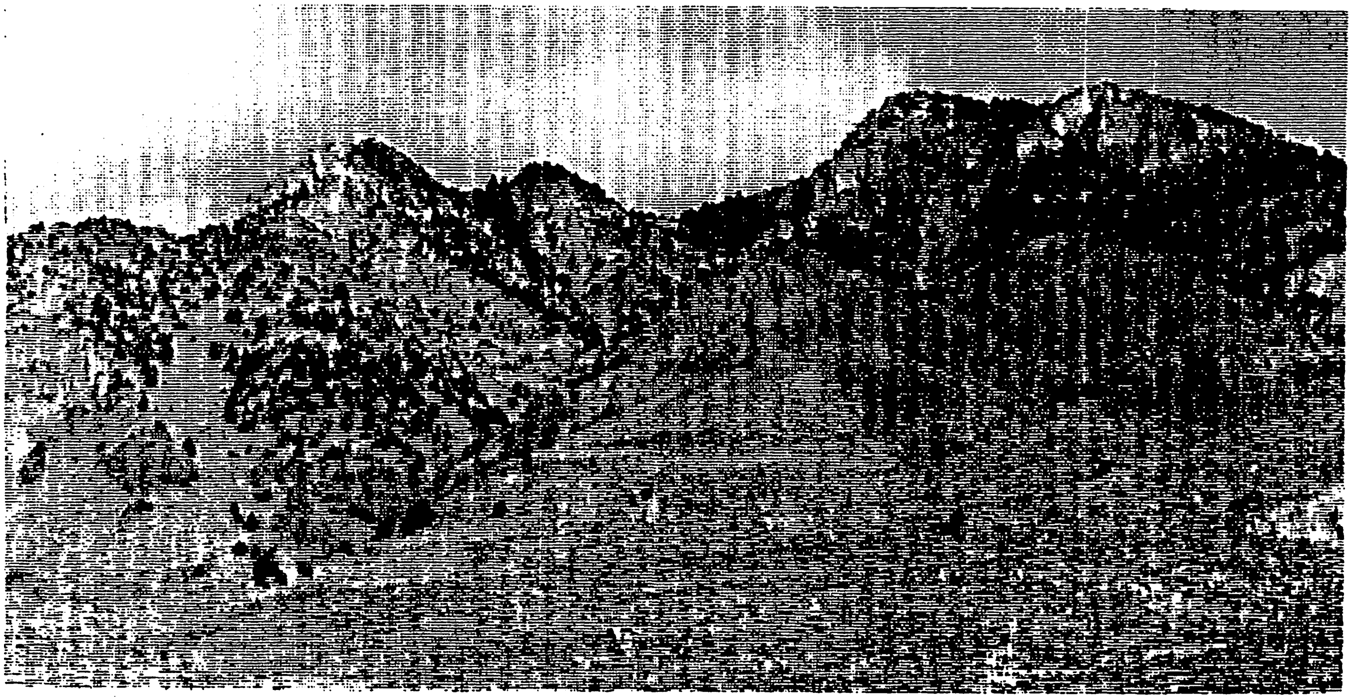
Principal collecting sites for Middle Cambrian fossils in Utah. The Spence Shale in the Wells-ville Mountains north of Brigham City, the Wheeler and Marjum Formations in the House Range west of Delta, and the Wheeler Shale in the Drum Mountains nothwest of Delta.



Paleogeographic model of Cambrian depositional environments along an east-west cross section of Utah, showin inner and outer detrital belts separated by the middle carbonate bank.

Recent collecting in the Utah formations have produced exciting diverse assemblages of both shelly and soft-bodied fossils. Each year additional new species are being discovered and there is a significant backlog of new material remaining to be studied and described.

In 1896, Robert S. Spence, an amateur collector of Garden City, Utah, sent some interesting well-preserved Middle Cambrian fossils to Dr. Charles D. Walcott at the Smithsonian National Museum. He sent additional material to him over the next 10 years which prompted Walcott to come to southern Idaho and northern Utah to collect and study. The type locality "Spence Gulch" in southern Idaho was named in honor of Spence and the "Spence Shale" derives its name from this source. Walcott originally described the Spence Shale as a member of the Ute limestone. Others have since placed the Spence in the Langston Formation and the Spence Tongue of the Lead Bell Shale. Dr. Richard A. Robison has recently suggested formational ranking to the Spence Shale pending further clarification of regional relationships. Its age, Lower Middle Cambrian, is close to that of the Burgess Shale.



Portion of Wellsville Mountains looking east to Miners Hollow

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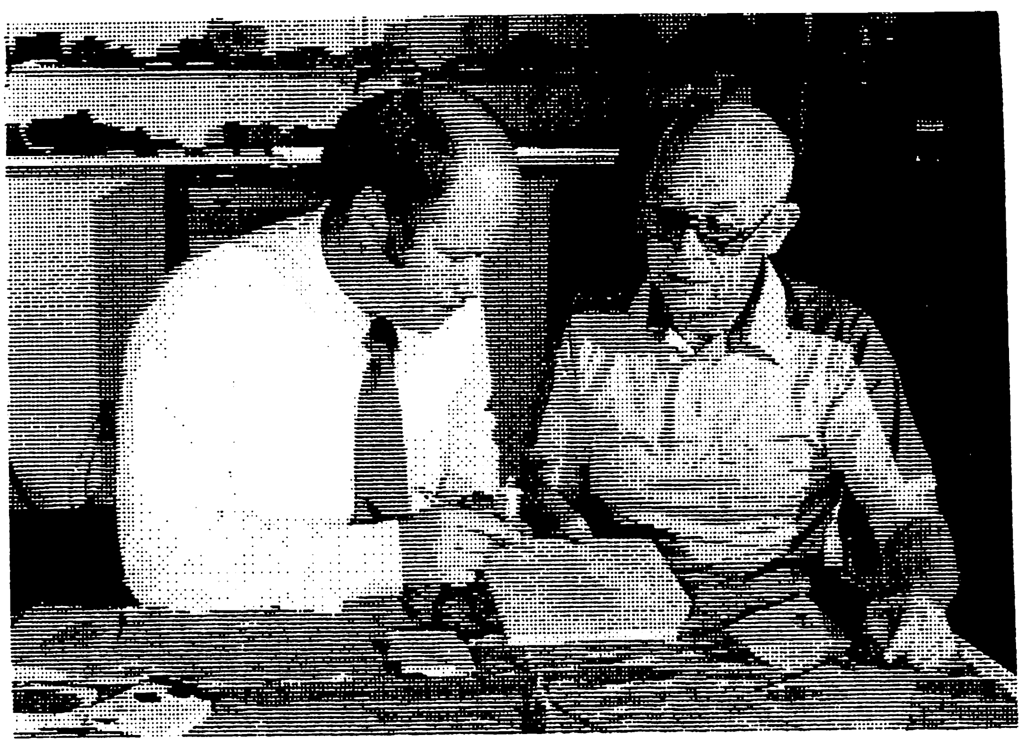
The Wellsville Mountains are best known for their steep ruggedness especially on the sunset side. It is the earth's steepest range, its ratio of height to width measured through the base is greater than any other mountain system. The Wellsvilles represent the northern extension of the Wasatch Range (the most westward range of the Rocky Mountains in the U.S.).

Numerous canyons cut into the westward side, exposing the rich fossil flora and fauna of the Middle Cambrian Spence Shale. The principal canyons where these shales are exposed include Donation Canyon, Miners Hollow, Cataract Canyon, Dry Canyon, Antimony Canyon, and Hansen Canyon. These canyons extend from just north of Brigham City for about 5 miles northward. These shales and interbedded limestone layers contain of of the most fossiliferous succession of lower Middle Cambrian rocks in western North America. In these outcrops are found numerous species of trilobites, sponges, green and blue-green algae, cyanobacteria, worms, phyllocarids, articulate and inarticulate brachiopods, hyolithids, eocrinoids, carpoids, a variety of trace fossils, and some of the enigmatic soft-bodied animals similar to those of the Burgess Shale of Canada.

The Spence Shale is also exposed at various sites in the Bear River Range of Utah and southern Idaho. The Wellsville mountain sites have been explored more fully and reveal the great diversity of life present in those ancient warm tropical seas. The Spence Shale is representative of the outer detridal belt sediments and run parallel to the ancient Cambrian coastline. The underlying Brigham Quartzite represents the sandy near-shore detrital belt facies.

Glade and Val Gunther quarrying for Spence Shale fossils in the Wellsville Mountains at Miners Hollow.



Val and Lloyd Gunther preparing some Middle Cambrian fossils

PARTIAL LIST OF FOSSILS FROM SPENCE SHALE OF WELLSVILLE MOUNTAINS

Algae & Cynobacteria

Acinocricus stichus
Marpolia spissa
Margaretia dorus
Morania fragmenta
Yuknessia simplex

Brachiopods

Acrothele affinis
Lingulella sp.
Micromitra modesta
Wimanella spencei

Enigmatic Fossils

Anomalocaris sp.
Eldonia ludwigi
Leanchoilia hanceyi
Utahcaris orion
Wiwaxia sp.

Phylocarids

Dioxycaris argenta
Tuzoia sp.

Trilobites

Achlysopsis punctatum
Alokistocare idahoense
Alokistocare laticaudum
Alokistocare mccollumi
Alokistocare mutablis
Alokistocare nannos
Alokistocarella sp.
Athabaskia bithus
Athabaskia wasatchensis
Bathyuriscus brighamensis
Bathyuriscus wasatchensis
Bythicheilus typicum
Caborcella cracens
Chancia ebdome
Dorypygee wellsvillensis
Elrathina spencei
Glossopleura bion
Glossopleura gigantea
Glossopleura granosa
Glossopleura prona
Glossopleura punctatum
Kootenia germana
Kootenia melindensis
Kootenia spencei
Kochina vestita

Cnidaria

Scenella radians

Echinoderms

Ctenocystis utahensis
Gogia granulosa
Gogia guntheri
Undescribed stylophoran
Undescribed eocrinoid

Hyolithids

Haplophrentis reesei
Hyolithes comptus
Hyolithes idahoensis

Priapulids

Ottoia prolifica
Selkirkia spencei
Selkirkia cf columbia

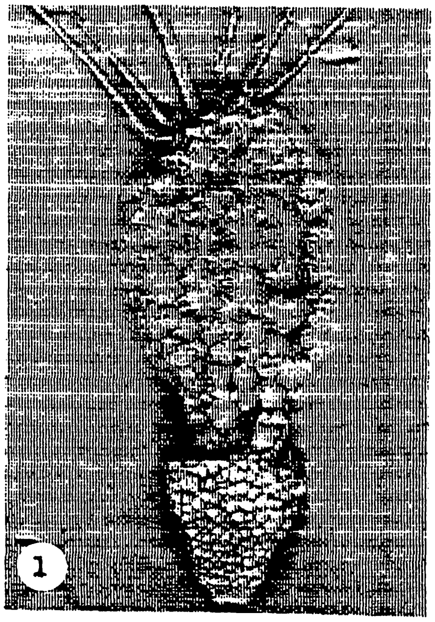
Worms

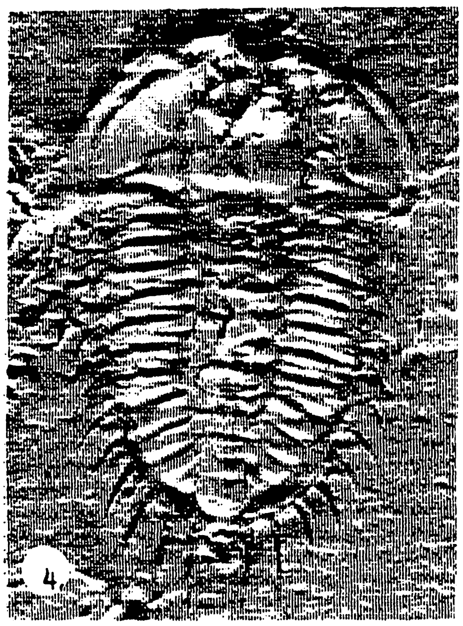
Canadia sp.
Palaeoscolex ratcliffei

Sponges

Choia sp.
Protospongia sp.
Vauxia magna

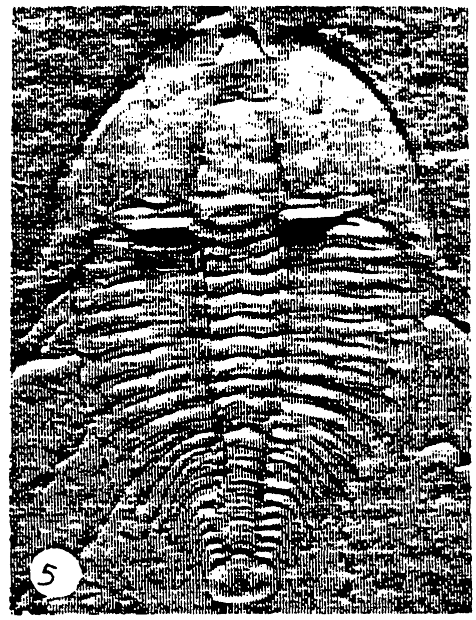
Ogygopsis typicalis
Olenoides evansi
Olenoides spencei
Oraspis limbus
Oryctocephalus walcotti
Oryctocare geikei
Pagetia lira
Pagetia fossula
Pagetia clytia
Peronopsis brighamensis
Peronopsis bonnerensis
Prohedinia spencei
Palmerella exiguus
Polypleuraspis sp.
Poliella milleri
Thoracocare minuta
Utia curio
Zacanthoides grabaui
Zacanthoides idahoensis
Zacanthoides prolixis

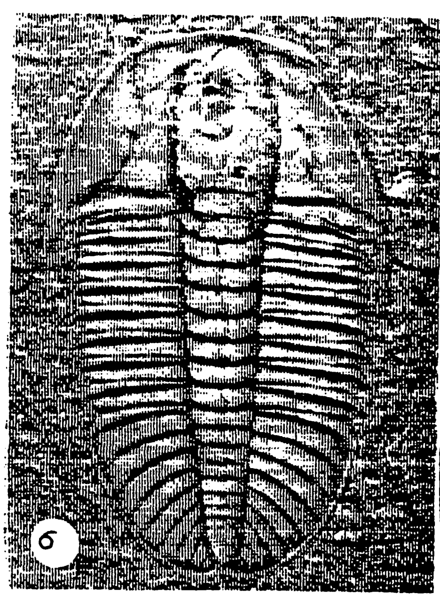


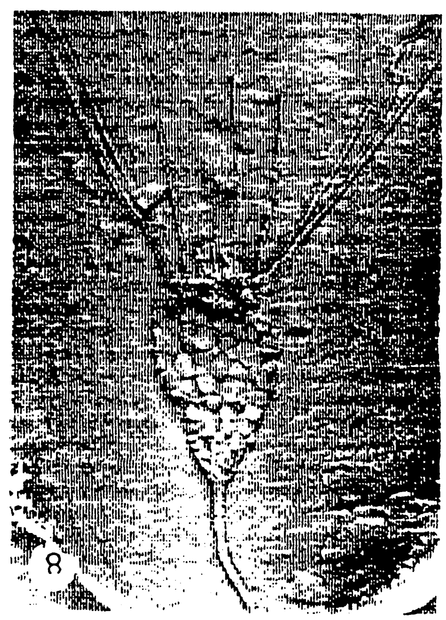


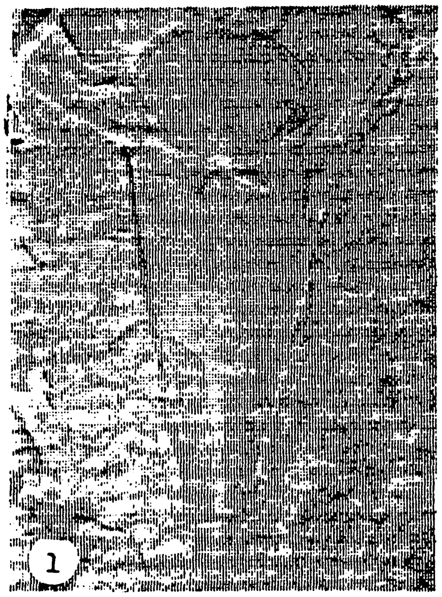
PHOTOS OF SOME SPENCE SHALE FOSSILS

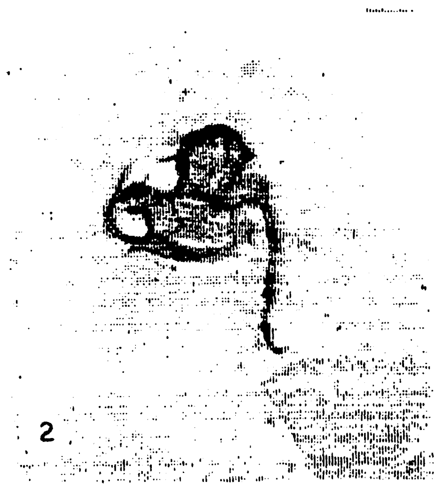
1. Gogia guntheri
2. Ctenocystis utahensis
3. Zacanthoides grabaui
4. Kootenia spencei
5. Alokistocare idahoense
6. Ogygopsis typicalis
7. Paleoscolex ratcliffei
8. Gogia jovalorum

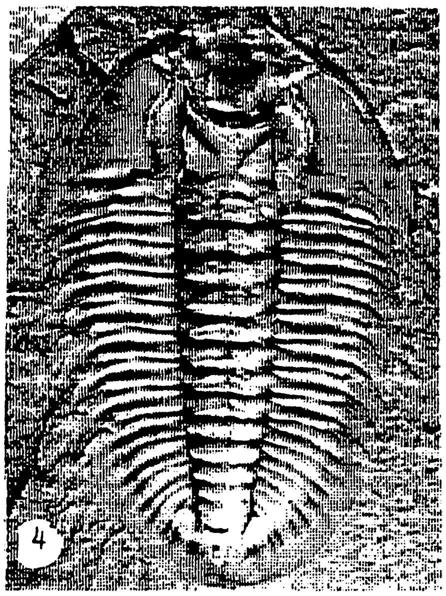






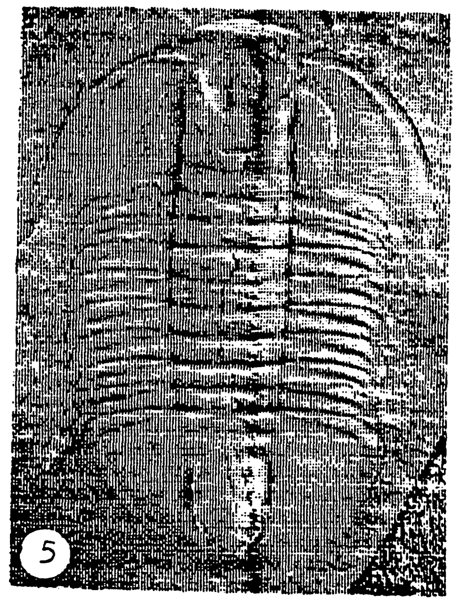


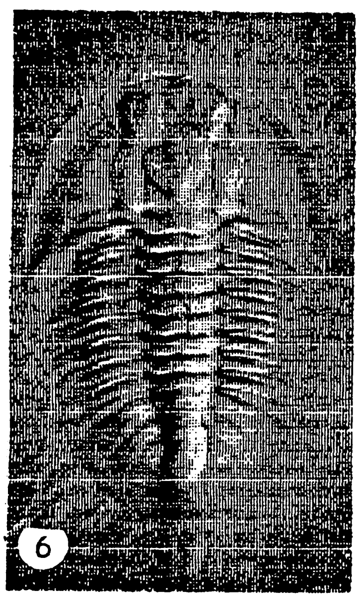


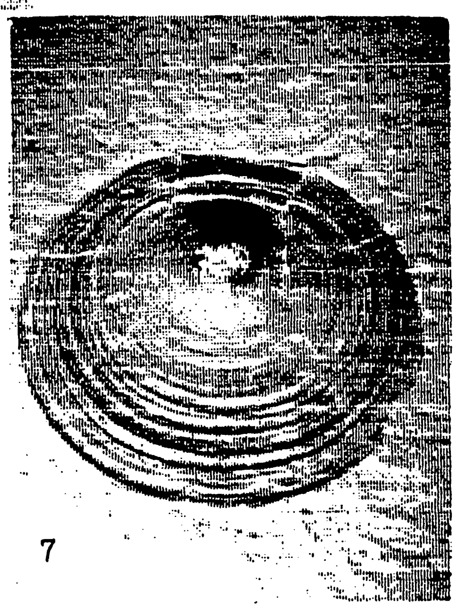


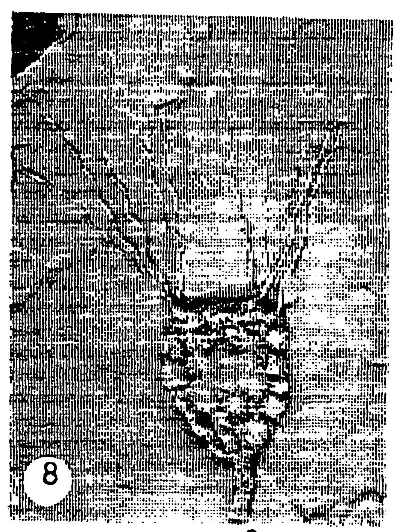
PHOTOS OF SOME
SPENCE SHALE FOSSILS

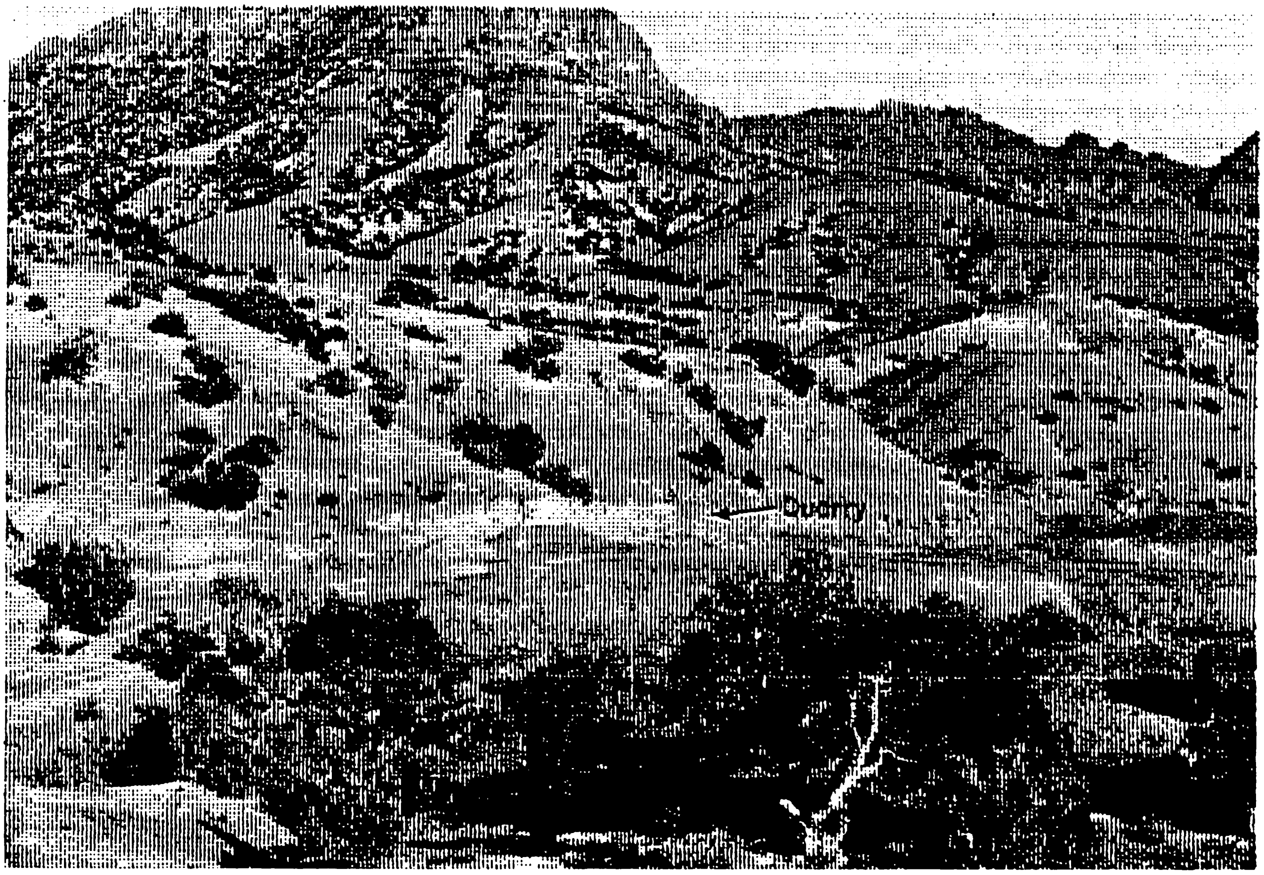
1 Haplophrentis reesei
2 Cothurnocystis sp.
3 Wiminella spencei
4 Athabaskia bithus
5 Glossapleura sp.
6 Athabaskia wasatchensis
7 Acrothele affinis
8 Gogia granulosa









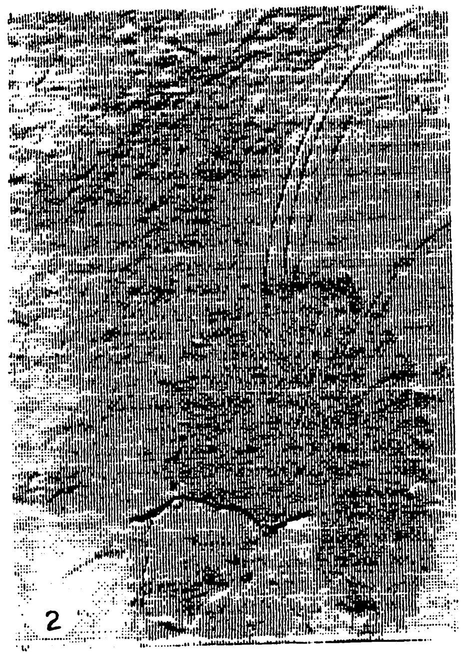


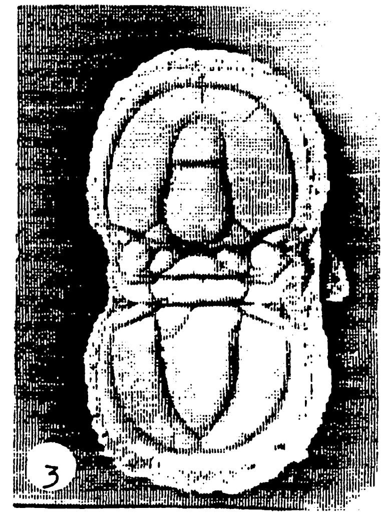
Type locality (Wheeler Ampitheater) of the House Range

The House Range is representative mostly of sediments laid down from the earliest Middle Cambrian to Late Middle Cambrian time. It represents an unusual continuous succession of fossils and presents a mecca for amateur and professional collectors alike because of their fine preservation and articulated condition. The Wheeler Ampitheater portion of the House Range is extremely popular as a trilobite collector's paradise. Millions of specimens, principally Elrathia kingii, Asaphiscus wheeleri, and Peronopsis interstricta have been mined and are found in museums, shops, and private collections throughout the world.

Much of the Middle Cambrian strata here were laid down in a transition zone between the middle carbonate bank and the outer detrital belt. The Wheeler Formation is representative of the deeper outer detrital belt of a large ocean embayment. The topography of the Wheeler Ampitheater today is a result of weathering and faulting of the outer detrital belt sediments exposing the extraordinary rich concentration of fossils.

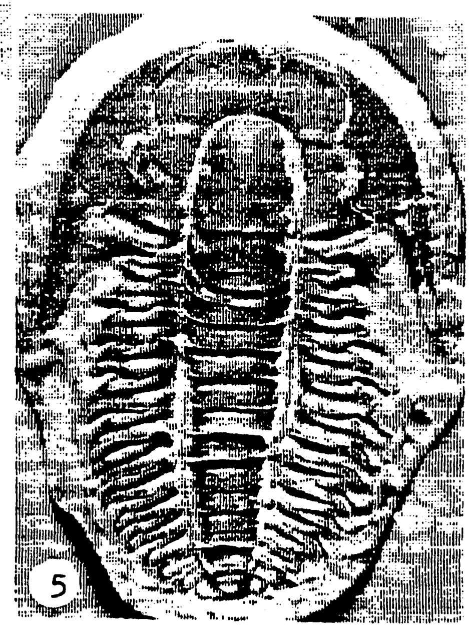
The Wheeler Formation was first described by Walcott who assigned the center of the Wheeler Ampitheater as the type locality. Here the formation is made up of a heterogeneous succession of highly calcareous shale (siltstone), shaly limestone, mudstone and thin flaggy limestone.

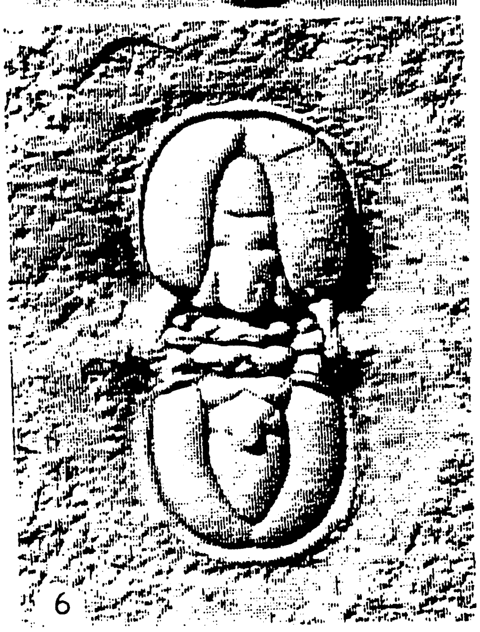


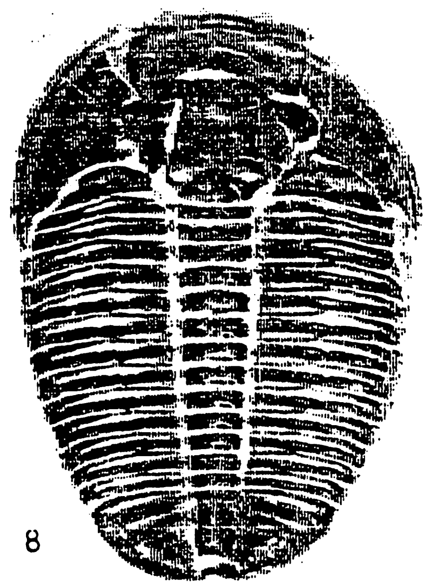


PHOTOS OF SOME WHEELER SHALE FOSSILS FROM THE HOUSE RANGE

1 Alokistocare harrisi
2 Choia carteri
3 Peronopsis interstricta
4 Brachyaspidion microps
5 Jenkinsonia varga
6 Ptychagnostus gibbus
7 Gogia spiralis
8 Elrathia kingii







PARTIAL LIST OF FOSSILS FROM WHEELER FORMATION OF THE HOUSE RANGE

Algae & Cynabacteria

Epiphyton sp.
Girvanella sp.
Morania fragmenta
Renalcis sp.
Margaretia dorus
Yuknessia simplex

Echinoderms

Gogia spiralis
Cothurnocystis bifida
Castericystis sprinklei

Hyolithids

Hyolithes sp.

Onchophorans

Aysheaia prolata

Trilobites

Alokistocare harrisi
Asaphiscus wheeleri
Baltagnostus centerensis
Bathyuriscus fimbriatus
Bolaspidella housensis
Bolaspidella wellsvillensis
Brachyaspidion microps
Brachyaspidion sulcatum
Elrathia kingii
Elrathina n. sp.
Hemirhodon amplipyge
Jenkinsonia varga
Modocia laevinucha
Naraoia compacta
Olenoides nevadensis
Peronopsis ferox
Peronopsis interstricta
Peronopsis segmenta
Ptychagnostus atavus
Ptychagnostus germanus
Ptychagnostus occulatus
Baltagnostus eurypyx
Hypagnostus parvifrons

Brachiopods

Acrothele subsidua
Linnarssonia ophirensis
Micromitra modesta
Prototreta attenuata
Nisusia sp.

Enigmatic Fossils

Chancelloria eros
Chancelloria pentacta
Chancelloria sp.

Monoplacophorans

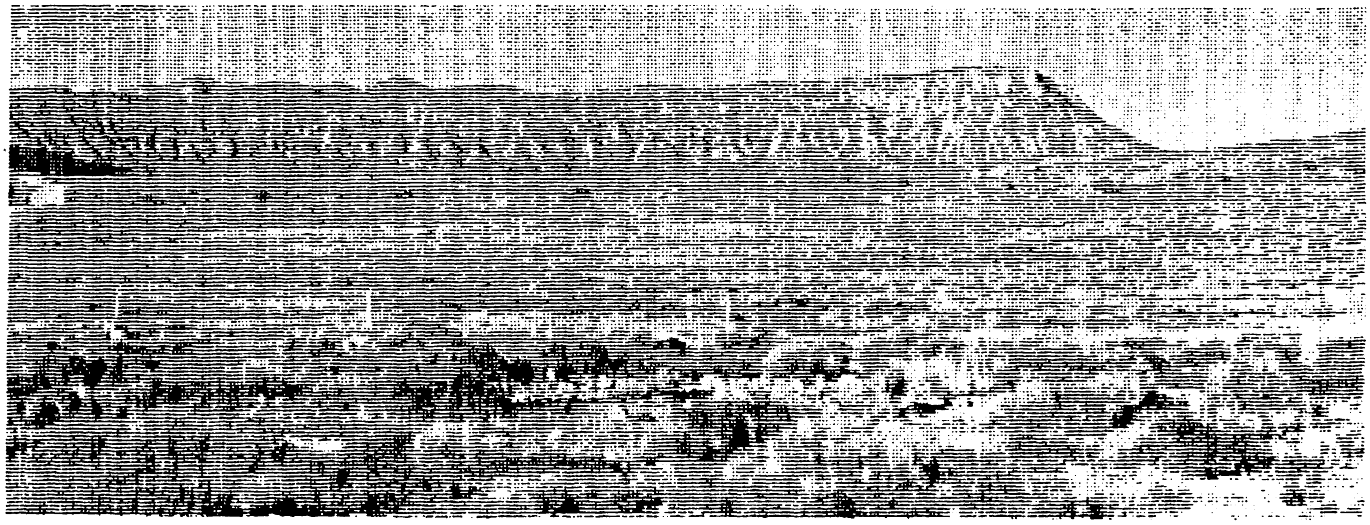
Latouchella arguta
Melopegma georginensis

Phylocarids

Perspicaris? dilatus
Pseudoarctolepis sharpi

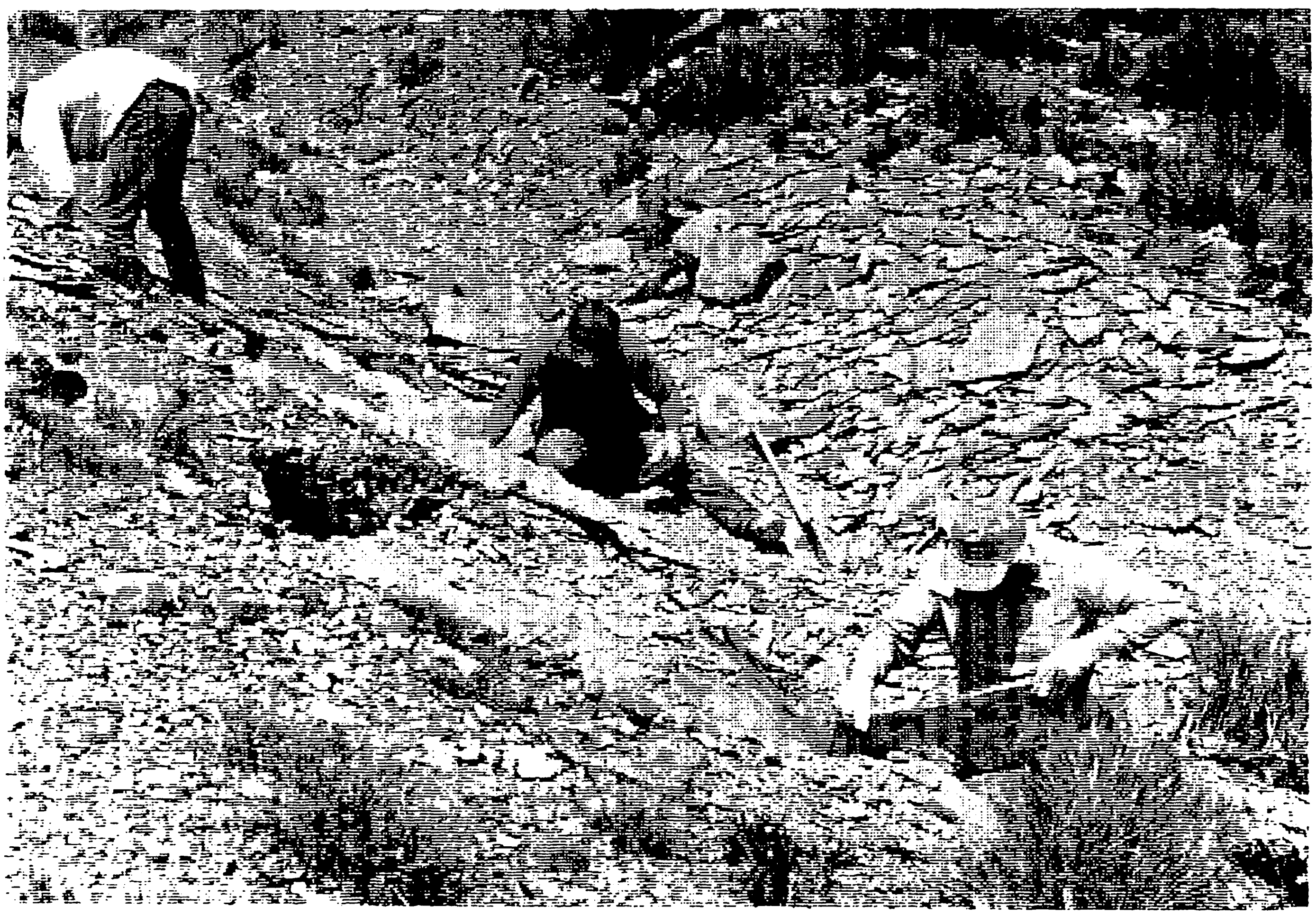
Sponges

Choia utahensis
Diagonella cyathiformis
Diagonella robisoni
Kiwetinokia spiralis
Kiwetinokia utahensis
Protospongia fenestrata
Sentinella draco

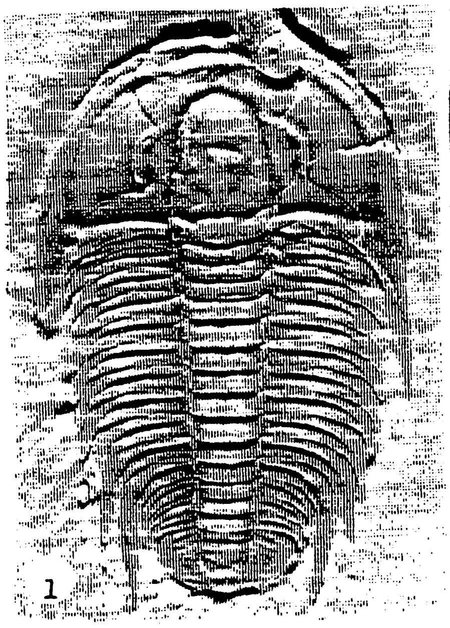


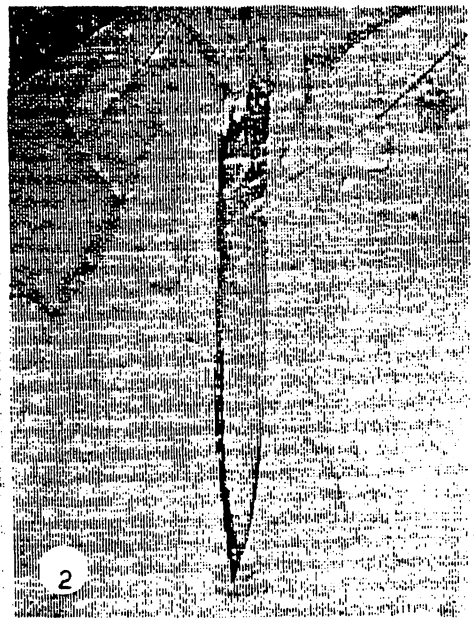
Type locality of the Marjum Formation

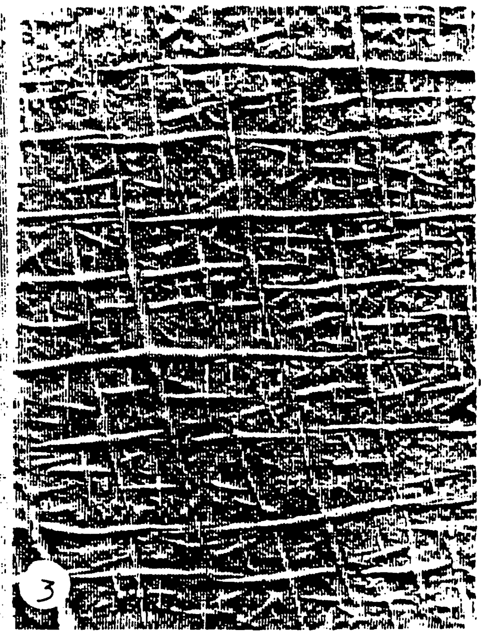
The Marjum Formation was also named by Walcott and briefly described as "gray to dark, more or less thin-bedded, arenaceous limestone." The type locality was designated "the cliffs on the south side of Marjum Pass, House Range, Utah." Robison further described the type locality as consisting of 60 percent thin-bedded, fine grained silty limestone, and about 38 percent shale and mudstone. A few beds of intraformational flat-pebble conglomerate, thin algal biostomes, and other miscellaneous rock types from less than 2 percent of the formation. The unit is expressed geomorphically as a series of slopes, ledges, and cliffs.

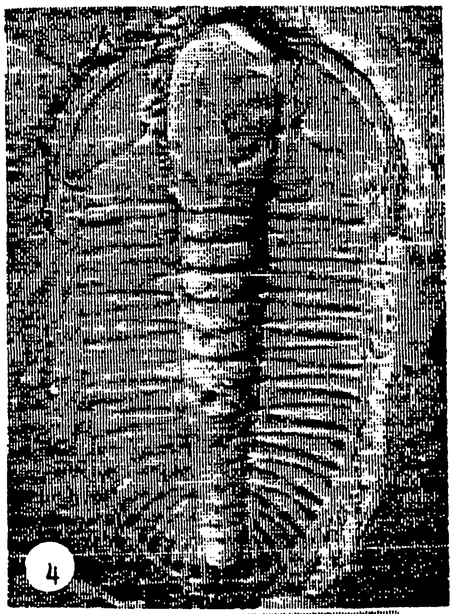


Quarrying Marjum Formation fossils at Red Wash, House Range.



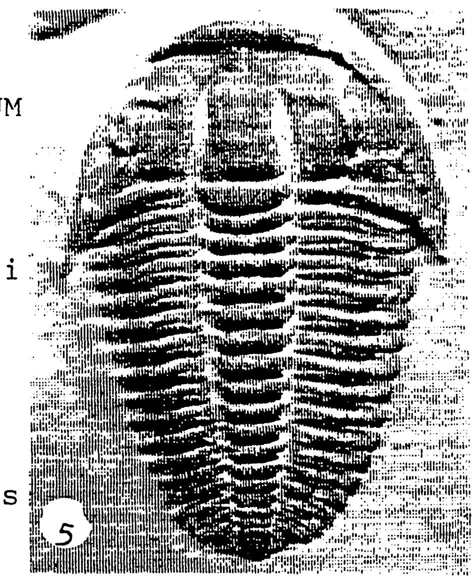


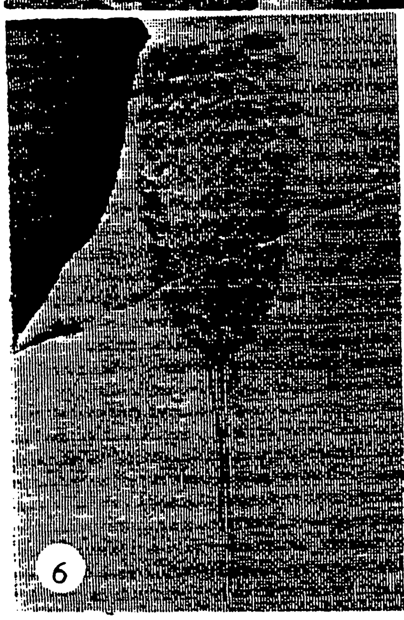


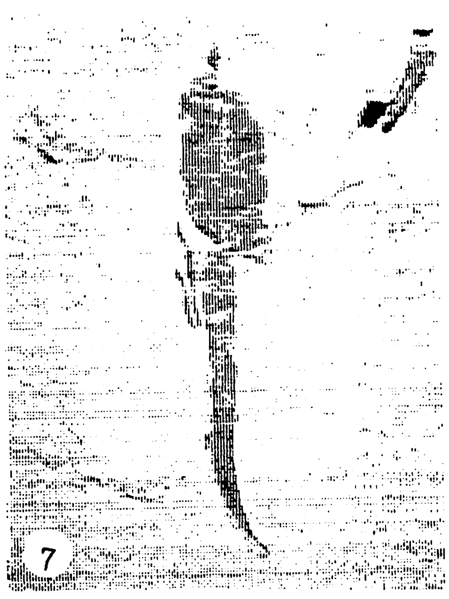


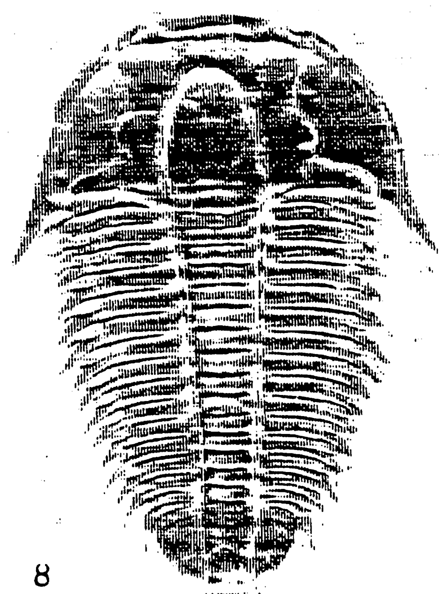
PHOTOS OF SOME MARJUM FORMATION FOSSILS

1 Modocia typicalis
2 Leptomitella metta
3 Protospongia hicksi
4 Olenoides marjumensis
5 Bolaspidella sp.
6 Diagonella cyathiformis
7 Castericystis vali
8 Utaspis marjumensis









PARTIAL LIST OF FOSSILS FROM MARJUM FORMATION OF THE HOUSE RANGE

Algae & Cynobacteria

Morania fragmenta
Margaretia dorus
Yuknessia simplex

Brachiopods

Acrothele subsidua
Lingulella sp.
Linnarssonia ophirensis
Micromitra modesta
Pegmatreta bellatula
Prototreta attenuata

Cnidaria ?

Cambrorhytium major

Echinoderms

Castericystis vali
Marjumicystis mettae
Totiglobus? lloydi

Enigmatic Fossils

Anomalocaris nathorsti
Chancelloria sp.

Hyolithids

Hyolithes sp.

Monoplacophorans

Latouchella arguta

Phylocarids

Branchiocaris pretiosa
Perspicaris? ellipsopelta
Tuzoia guntheri

Pogonophorans

Hyolithellus sp.

Priapulids

Ottoia prolifica

Trilobites

Alokistocare harrisi
Asaphiscus wheeleri
Baltagnostus centerensis
Bathyuriscus elegans
Bathyuriscus fimbriatus
Cotalagnostus sp.
Hemirhodon amplipyge
Hypagnostus parvifrons
Lejopyge lundgreni
Lejopyge rigbyi
Marjumia typa
Modocia laevinucha
Modocia typicalis
Peronopsis interstricta
Ptychagnostus atavus
Ptychagnostus germanus
Ptychagnostus michaeli
Ptychagnostus occultatus
Olenoides superbus
Olenoides marjumensis
Schmalenseeia sp.
Trymataspis depressa
Utaspis marjumensis

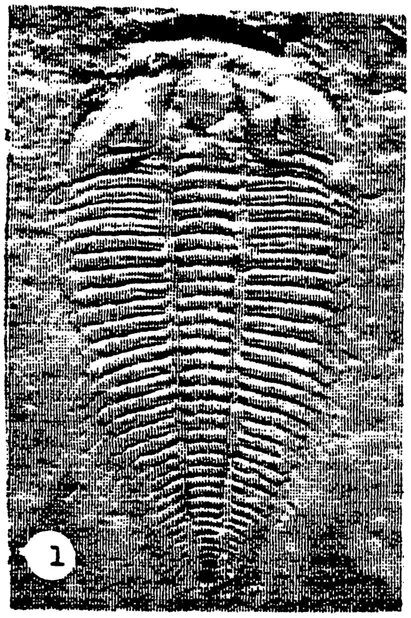
Sponges

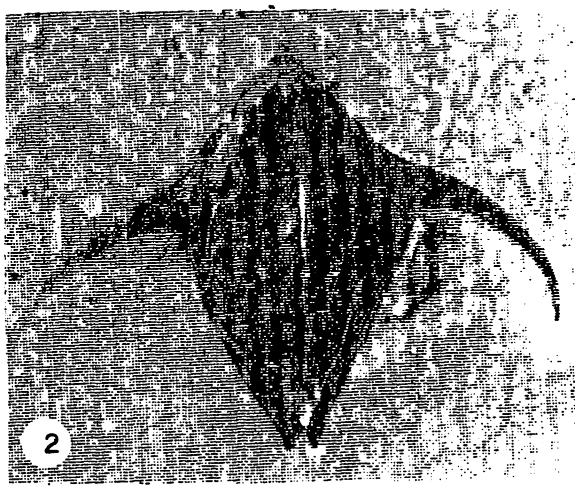
Choia carteri
Choia hindei
Choia utahensis
Hamptonia bowerbanki
Hazelia palmata
Leptomitella metta
Diagonella cyathiformis
Diagonella hindei
Diagonella sp.
Hintzespongia bilamina
Kiwetinokia spiralis
Kiwetinokia utahensis
Protospongia hicksi
Protospongia? elongata
Protospongia fenestrata
Ratcliffespongia perforata
Testispongia vanula
Valospongia gigantis

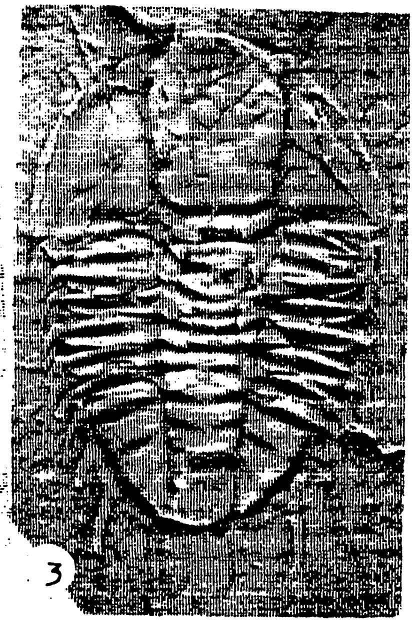
Portion of the southern Drum Mountains showing some Upper Wheeler Shale exposures.

The Wheeler Shale Formation in the southern Drum Mountains is made up of platy limestone and shale deposits which are representative of the shallow carbonate bank between the inner and outer detrital belts. It represents deposition in a protected, low-energy, shallow subtidal environment on the northeastern margin of the House embayment. Thickness of this formation ranges up to 304 meters in the Drum Mountains. It contains a diverse fossil assemblage although trilobites are the most commonly preserved fossils.

This formation in the Drum Mountains has contributed significantly to the growing list of new life forms of the Cambrian not previously reported. An example is a recent discovery of a new myriapod-like fossil that extends the record of myriapod-like body fossils back by approximately 100 million years! It represents the earliest known uniramous arthropod, and may have special significance with respect to the ancestry of terrestial centipedes, millipedes and insects.

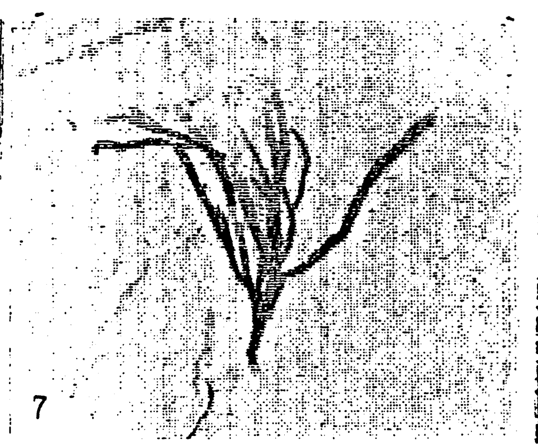


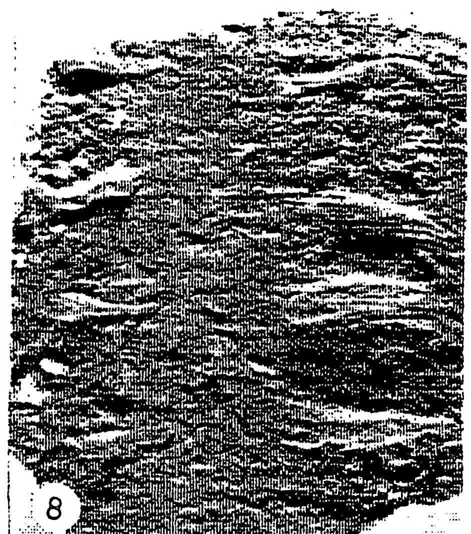




PHOTOS OF SOME WHEELER SHALE FOSSILS FROM THE DRUM MOUNTAINS

1 Alokistocare harrisi
2 Pseudoarctolepis sharpi
3 Kootenia sp.
4 Bathyuriscus fimbriatus
5 Olenoides nevadensis
6 Asaphiscus wheeleri
7 Yuknessia simplex
8 Unidentified trackway





PARTIAL LIST OF FOSSILS FROM WHEELER FORMATION OF THE DRUM MTS.

Algae & Cynabacteria

Epiphyton sp.
Girvanella sp.
Morania fragmenta
Renalcis sp.
Margaretia dorus
Yuknessia simplex

Echinoderms

Ctenocystis colodon
Gogia spiralis

Monoplacophorans

Latouchella arguta
Melopegma georginensis

Priapulids

Selkirkia willoughbyi
Selkirkia sp.

Trilobites

Alokistocare harrisi
Asaphiscus wheeleri
Baltagnostus centerensis
Bathyuriscus fimbriatus
Bolaspidella drumensis
Brachyaspidion microps
Brachyaspidion sulcatum
Elrathia kingii
Jenkinsonia varga
Kootenia n. sp.
Modocia brevispina
Olenoides nevad ensis
Olenoides n. sp.
Peronopsis interstricta

Brachiopods

Acrothele subsidua
Lingulella sp.
Micromitra modesta
Nisusia sp.
Prototreta attenuata

Hyolithids

Hyolithes sp.

Myriapod

Cambropodus gracilis

Phylocarids

Perspicaris dilatus
Pseudoarctolepis sharpi

Sponges

Vauxia sp.

AN UNUSUAL OCCURENCE IN THE DEVONIAN OF OKLAHOMA

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White Mound is the locality most people would think about if the Devonian of Oklahoma was mentioned; however there is a much more exciting horizon for unusually fine fossils. The strata exposed at White Mound is the Haragan Formation, and for years this was thought of as the only trilobite producing horizon in Oklahoma of Devonian age.

The horizon we work is, we feel, much more exciting than the Haragan. It is about 85 feet higher and is the Cravat Member of the Bois D'Arc Formation. This zone was virtually uncollected at the time I found that it held a treasure trove of exquisitely preserved fossils.

Amsden, in working the stratigraphy of Oklahlma named the formation above the Haragan but felt they could be facies of the Haragan. In many localities the Bois D'Arc is above the Haragan and at no locality that we know can it possibly be a lateral facies of the Haragan. It is not deposited in some areas or absent by erosion and this is also true of the Haragan.

Locally the Cravat zone in the Bois D'Arc is very rich in fossils and in some areas the trilobite bearing beds are thicker (up to 5 feet). At Old Hunton townsite the trilobites are rather scarce and not too well preserved. The producing horizon at that locality is rather thin, probably not more than 1 foot. Further south, on our lease, the trilobite beds are very rich and preservation is exquisite in most cases.

Most of the trilobites in the Cravat are undescribed species as might be expected since no earnest collecting was ever done in this horizon before we started mining. A few specimens were picked up on the surface by paleontologists who recognized that this was not Haragan and as a result five trilobites were said to be present in this horizon.

When Campbell described the trilobites of the Devonian of Oklahoma the collection at the University of Oklahoma (on which he based his study) was in a mess as far as good stratigraphic data was conserned. Most of the material that had been accumulated during early years of collecting had been dumped into "Collections from the Haragan". In many cases fossils that had weathered down slope from the overlying Bois D'Arc were included in the Haragan collection. Due to this error a few Bois D'Arc forms were described but credited to occurence in the Haragan.

Besides trilobites there are crinoids, cystoids, graptolites, corals, bryozoans, sponges, cephalopods, brachiopods, bivalves, gastropods, hyloithids, conularia, scolecodonts, ostracods and other micro-fossils in the Cravat Member of the Bois D'Arc.

The trilobite fauna is the most exciting because of the incredible preservation, variety and rarity present. Paciphacops is the most common trilobite, followed by Huntonia, Leonaspis, Cordania, Dicranurus, Odontochile, Breviscutellum, Harpidella, Otarion and Coniproetus.

Deposition was in a fairly shallow sea with very little current action. This is evident by the many perfect trilobites and scolecodont jaws found in living position.

Geological Enterprise's lease takes in about a mile of outcrop which is enhanced at the South end by pyrite replacement of many brachiopods and occasionally a trilobite. We have excavated a very large quarry in this area by bulldozing and blasting. The overlying Firsco was removed by bulldozing (this horozon also has a distinctive trilobite fauna), as was the relatively uninteresting upper porton of the Cravat. As we worked back into unweathered limestone the pyrite replacements are bright and stable. On the surface these are altered to hematite and limonite.

This lease probably encompases the richest and best preserved trilobite fauna from the Devonian of the U.S. A good days work quarrying almost always produces around 100 perfect trilobites plus many other fossils.

This locality can not compete with the Burgess Shale as a Lagerstatten but we do feel that it is among the best of the little known fossil localities of the world.

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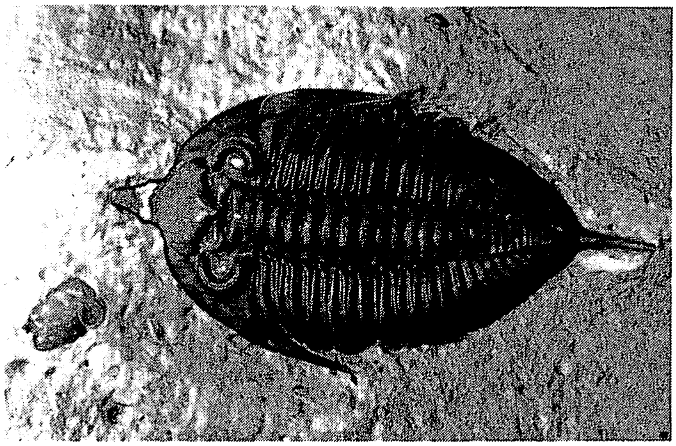
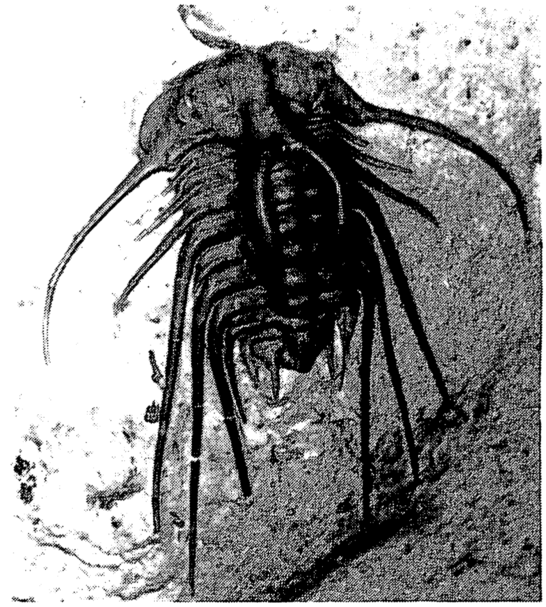
AMSDEN, T.W., 1960 Hunton Stratigraphy part 6, Stratigraphy and paleontology of the Hunton group in the Arbuckle Mountains of Oklahoma. Oklahoma Geological Survey bulletin 84, p 311. 17 pl.

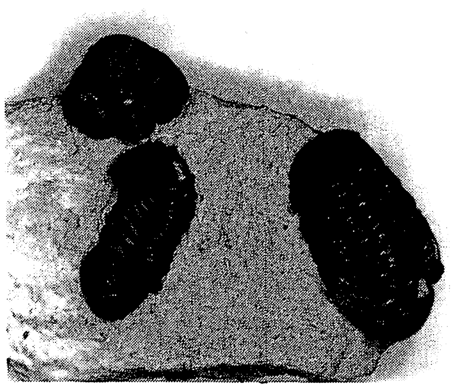
Campbell, K.S.W., 1977, Trilobites of the Haragan, Bois D'Arc and Frisco Formations (Early Devonian) Arbuckle Mountain Region, Oklahoma. Oklahoma Geological Survey bulletin 123, p 227. 40 pl.



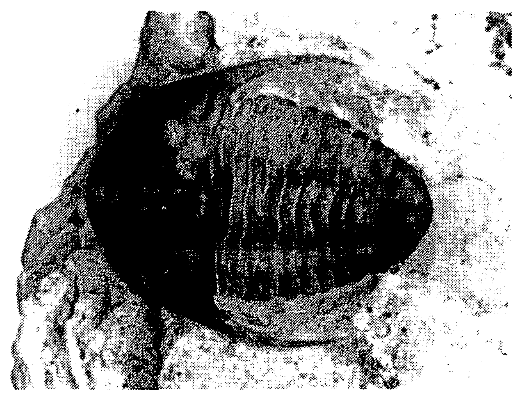
ODONTOCHILE



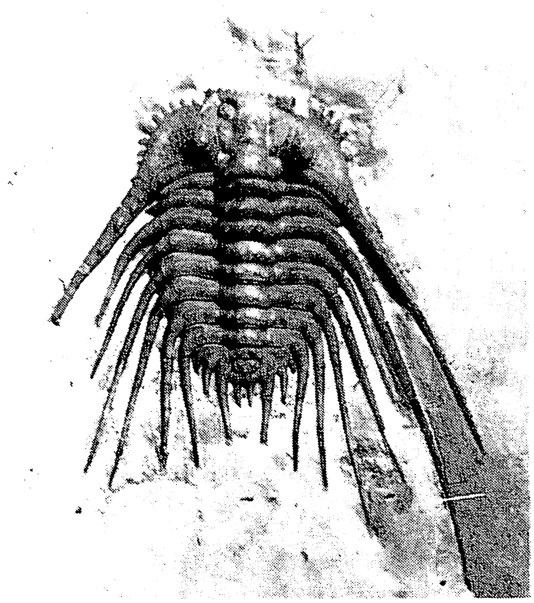
DICRANURUS



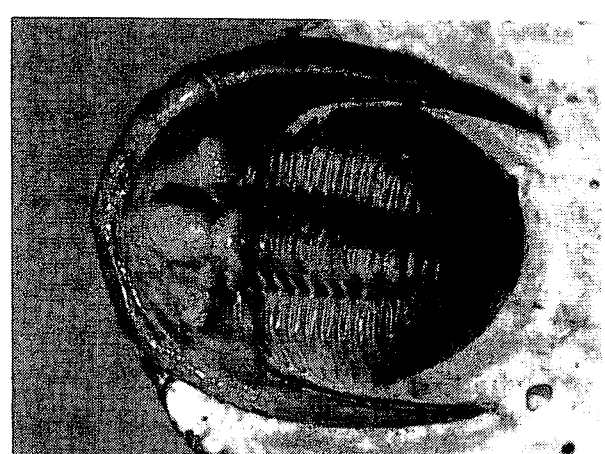
PACIPHACOPS
(3 in matrix block)



HARPIDELLA axitiosum



LEONASPIS



CORDANIA

THE BROWNSPORT GROUP OF THE SILURIAN SYSTEM OF THE WESTERN TENNESSEE RIVER VALLEY

INTRODUCTORY STATEMENT

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In 1908 Foerste named the Silurian beds above the Dixon Formation the " BROWNSPORT BEDS", for the Brownsport Furnace in Decatur County, Tennessee. From a study of his descriptions of this new formation at different locations, it is apparent that he included all the beds that now comprise the Beech River, Bobs, Lobelville and Decatur formations. Professor W. F. Pate, and Dr. W. S. Bassler studied this sequence in more detail than previous writers, recognized and named the Beech River, Bob and Lobelville as formations. They included only these three in the redefined "BROWNSPORT GROUP". In 1910 Miser changed the group to a formation, including the Beech River, Bob and Lobelville as members. This classification was followed by Jewel in 1931 and Wade in 1940, who accepted the Decatur limestone as a formation, agreeing with Pate and Bassler. It is the general belief now that these three members have all the requisites of the definition of a formation, and thus are used as such in the "BROWNSPORT GROUP".

The Western Tennessee River Valley has been a classic ground for paleontologists ever since Dr. Gerard Troost, the first geologist for the State of Tennessee, carried to the 1849 meeting of the American Association for the Advancement of Science, a series of fossil crinoids collected by him in Decatur and Perry Counties; which he submitted to Prof. Louis Agassiz with an imposing list of genera and species, of which he had prepared a monograph with full descriptions. Dr. Troost left this material at the Smithsonian Institution for publication on July 18, 1850. Troost died in August of the same year. His manuscript, in accordance with a custom of the institution was submitted for revision to a committee consisting, in this case, of Prof. James Hall and Prof. Louis Agassiz. The fossils and manuscript was sent first to Prof. Hall, who transmitted them to Prof. Agassiz for revision. When at the end of five years the manuscript was still unrevised, Agassiz returned it to Prof. Hall. Hall retained the fossils and the manuscript for the remainder of his life time, more than forty years. While the manuscript was in Hall's possession he published four of Troost's genera, quoting Troost's description of three of them.

He also published descriptions of ten other species the names of which had already been published by Troost, [1850, pp.60-62].

This monograph was finally published as Bulletin 64 by the Smithsonian Institution as "A CRITICAL SUMMARY OF TROOST'S UNPUBLISHED MANUSCRIPT ON THE CRINOIDS OF TENNESSEE", by Elvira Wood of Columbia University, New York City, April 15, 1909.

In 1847, Dr Troost invited the eminent paleontologist, C. Ferdinand Roemer to visit his famous outcrop of fossils in the Silurian System of the Western Tennessee River. The result of Dr. Roemer's extensive collecting and research were published in 1860 as "DIE SILURISCHE FAUNA des WESTLICHEN TENNESSEE", Breslau, Germany. Following these two pioneers, Prof. J. M. Safford, as the state geologist, made a study of the Silurian formations of Tennessee. His accounts of the stratigraphy were published in the American Journal of Science in 1861, and again in his report of 1869 he gave the collective name "MENISCUS", to what is now known as the "BROWNSPORT GROUP". His collections are now in the Museum of Vanderbilt University, Nashville, Tennessee.

The Beech River Formation was named for exposures along the Beech River in Decatur County, Tennessee by Pate and Bassler in 1908. It was classed by them as "THE BEECH RIVER FORMATION", of the Brownsport Group. This terminology is in general acceptance today; however, in 1947, Thomas W. Amsden presented a lengthly paper as a dissertation for the degree of Doctor of Philosophy at Yale University, entitled: "Stratigraphy and Paleontology of the Brownsport Formation (Silurian) of the Western Tennessee", in which he maintaines and attempts to prove the Beech River, Bob and the Lobelville are members of one formation, "THE BROWNSPORT FORMATION", thus disagreeing with Wade, Jewel, Pate, Bassler and Charles W. Wilson, Jr. along with all the others I have read. So I will continue to use the term, "BROWNSPORT GROUP".

It's an argillaceous shale, of which the western edge lies along the western edge of Hardin And Decatur counties and it's eastern edge is along the eastern edge of Wayne and the western edge of Hickman County. The northern boundary dips into the Tennessee lobe of the Illinois basin, the southern boundary dips into Alabama. The greatest thickness is at Clifton, Tennessee. This point representing the saddle between the Nashville dome and the southeastern extension of the Ozark dome.

The Beech River formation overlies the Dixon formation with apparent conformity and is overlain by the Bob limestone with a very sharp contrast at the contact zone. However, where the Bob limestone has been removed by erosion, we find the famous "BALD CEDAR GLADES", which are internationally known for the great variety and abundance of beautifully preserved fossils of sponges, corals, brachiopods, crinoids, blastoids and the famous blastoid "TROOSTOCRINUS".

The first publication on the fossils of the Beech river formation was 1n 1860 by Roemer. Since then these glades have been visited by many prominent collecting geologists, among them; Col. Sydney S. Lyon, Prof. A. H. Worthen of Illinois, Dr. Carl Rominger of Michigan, Mrs. J.M. Milligan and many others.

The Bob limestone was named by Pate and Bassler in 1908 for the bluff one mile below Bob's landing, along the west bank of the Beech River and Lobelville formations. It is well exposed at the Brownsport Furnace in Decatur County and At Lady Finger Bluff, Mousetail Landing and White Oak Creek in Perry County, where we dig in the beds of Conchidium lindenense, Meloncrinus oblongus, Technocrinus niagarensis and the Sphaeroxerus sp. if you are lucky.

The Lobelville formation was also named by Pate and Bassler in 1908 for the exposures near Lobelville, Tennessee in Perry County. This formation is an argillaceous glade forming alternation of limestone and shale between the relatively silt free Bob and Decatur limestones. The Lobelville formation is so similar to the Beech River lithologically that I will omit the description of the formation at this time, since it has the same general characteristics. The Lobelville seems to be restricted to parts of Wayne, Hardin, Perry, Decatur and Hickman counties. It is overlain conformably by the Decatur limestone or by the Chattanooga shale, which is of Mississippian age. The Lobelville formation like the Beech River is very fossiliferous, with many of it's glades covered with corals, Crinoids, Crinoid parts, etc. Pate and Bassler not only named the formation but also named many of the corals found in the Lobelville formation.

In 1926, Frank Springer reported finding many crinoids, brachiopods and corals in the Lobelville formation.

The most interesting feature about the "BROWNSPORT GROUP" is the development of the many glades with little or no vegetation, leaving the surface bare to erode, thus, exposing the many fossils for us to have for the taking.

In the summer of 1906 and 1907, Pate and Bassler were hired by Frank Springer to find an outcrop that was not weathered and to quarry for fossils in place (in situ). This they did along the bank of the Beech River, one mile north of Decaturville, Tennessee. They found a total of 95 species of crinoids, 59 fo which were new, distributed among 33 genera, besides a blastoid and a few cystoids, in a very limited area, but exploring all three zones of the Beech River formation, namely, the Eucalyptocrinus zone, the Troostcrinus zone and the Coccocrinus zone

This is a shaly limestone about 60 feet in depth, however most of the collecting today is surface hunting on the Bald Cedar Glades, which is the most fascinating collecting area I have had the privilege to collect, or carry others to collect. Can you imagine collecting five filter feeders from one ten foot square area without digging? Ask David Jones of Worthington, Minn., or better yet come see for yourself.

I have included a few pictures of some of the specimens now on display in my Museum at Petersburg, Tennessee, all pictures are X 1 natural size.

SPRINGER: AMERICAN SILURIAN CRINOIDS PLATE 33

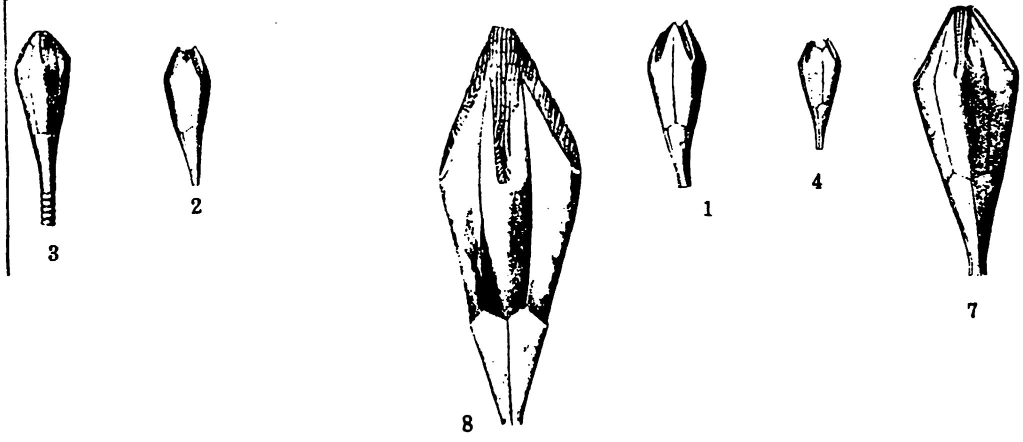


PLATE 33

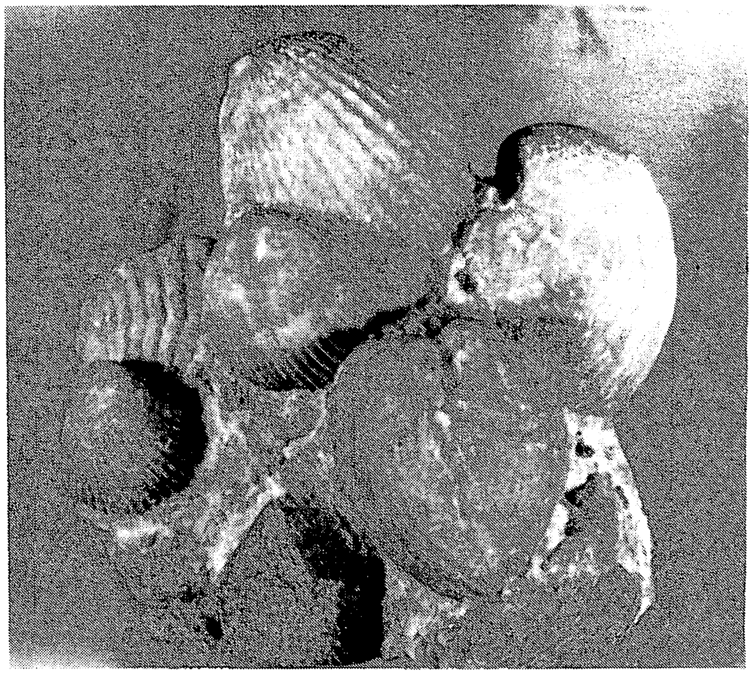
(All figures natural size unless otherwise stated) PAGE

Troostocrinus reinwardti (Troost) 141

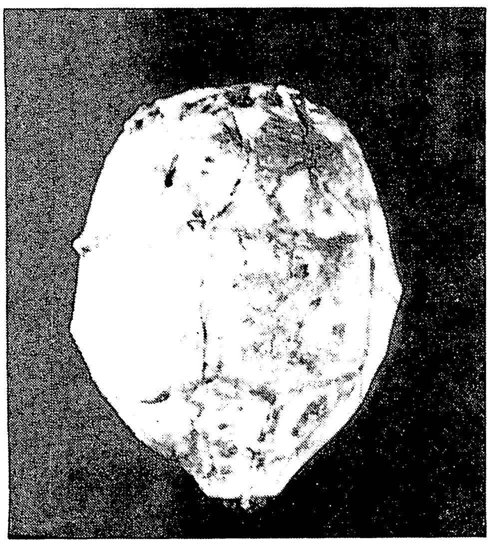
FIGS. 1, 2. R. ant. and post. views of average specimens.
3. R. post. view of similar specimen with part of stem.
4, 5, 6. Lateral views of 3 small specimens.
7. Ant. view of maximum specimen.
8. Specimen with the brachioles in place × 2.
Troostocrinus zone of Beech River formation; Decatur and adjoining counties, Tennessee.

FOSSILS OF THE BROWNSPORT GROUP

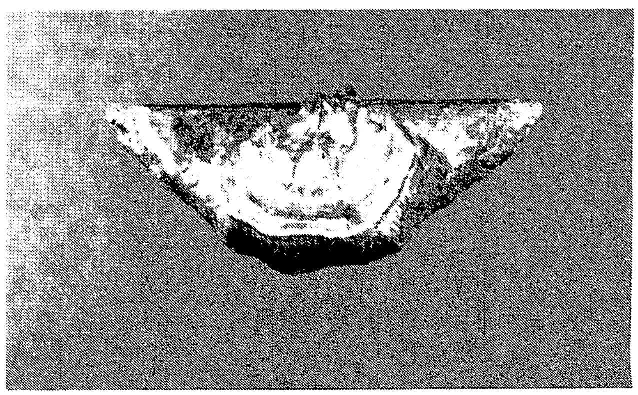
NAUTILOID



CONCHIDIUM LINDENENSE

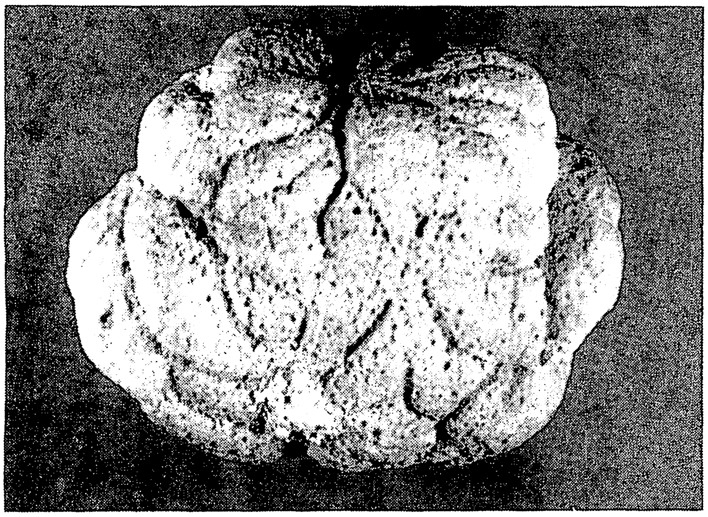


CARYOCRINITES ORNATUS

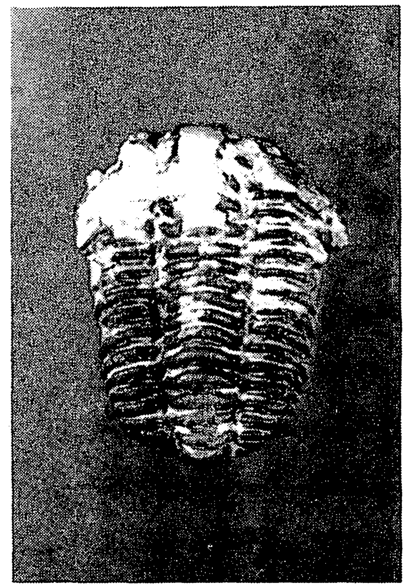


LEPTAENA sp.

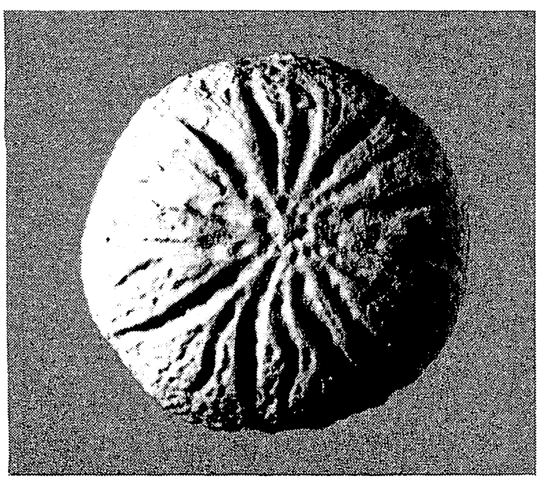
All fossils x1 except Conchidium x2.5



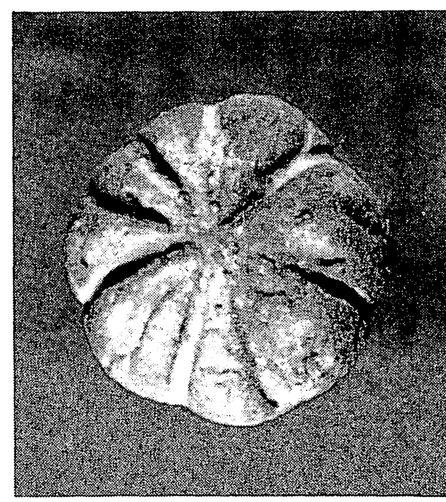
ASTYLOMANON GLANDULOSUM



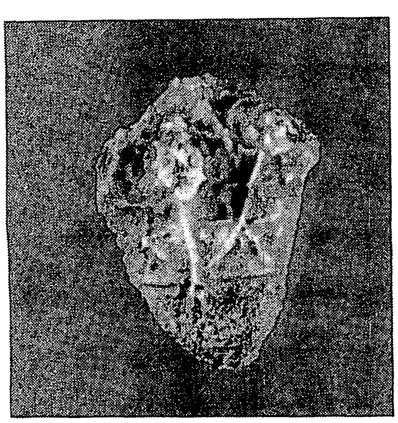
CALYMENE CELEBRA



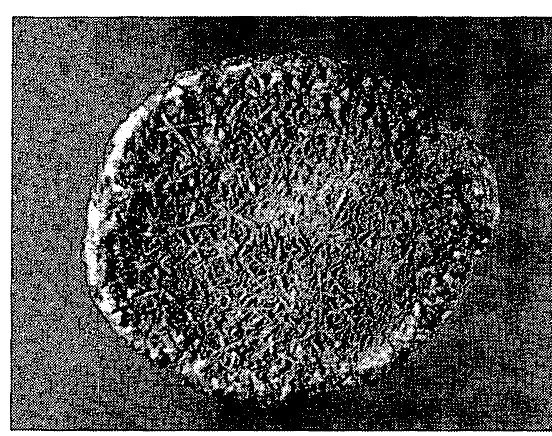
ASTYLOMANON VERRUCOSUM



CARYOMANON INCISO-LOBATUM



LAMPTIROCRINUS TENNESSEENSIS



ASTRAEOSPONGIA MENISCUS

All fossils x1

AN HISTORICAL OVERVIEW OF THE GEOLOGY AND PALEONTOLOGY

OF THE FALLS OF THE OHIO

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Crestwood, KY 40014

INTRODUCTION AND LOCATION

The Falls of the Ohio River is located just below and adjacent to the McAlpine Dam and below the Penn-Central railroad bridge. This area is situated between Louisville, Kentucky and Clarksville, Indiana. Since the completion of the McAlpine Dam in the early 1950's, access to the Falls has been limited to the Indiana shore of the Ohio River by way of Riverside Drive, Jeffersonville, Indiana. (see fig. 1-2).

The "Falls" of the Ohio is actually a series of rapids, with a verticle drop of twenty six feet over a distance of about four miles. These rapids have exposed a section of bedrock that consists of the Louisville Limestone (Middle Silurian), the Jeffersonville Limestone (Middle Devonian), the Beechwood Limestone (Middle Devonian) and the New Albany "Black " Shale (Upper Devonian). After the construction of the McAlpine Dam and the associated locks, the bulk of the remaining exposures consists of large flat shelves of the Jeffersonville Limestone covering many acres, (the result of dimension stone quarry operations).

THE EARLY DAYS - BEFORE THE CORPS OF ENGINEERS

The early explorers of the Falls region described the Falls as a frozen sea bottom with many "buffalo horns". These reports indicate that there were numerous free standing coral colonies, some of which were the height of a man and several times that size across. Some of these early explorers were; the French explorer LaSalle (1669), George Rogers Clark, enroute to Kaskaski (1771. It is rumored that Thomas Jefferson may have visited the Falls area sometime after 1765. It is known that Thomas Jefferson had Colonel George Croghan visit the Falls in conjunction with an expedition to Big Bone Lick in Boone County, Kentucky. However these collections were lost when the field party was attacked by Indians. Also Benjamin Franklin shipped a large collection of fossils to London, which was thought to have contained fossils from the Falls.

At any rate large collections were carted away to Europe. Corals from the Falls of the Ohio can be seen in almost any Natural History Museum in the world. The best European collections can be found in Germany (Paleontologisches Institut, Bonn University) and France (Ecole des Mines, Paris). Large United States collections include the United States National Museum, the Yale-Peabody Museum, the New York State Museum, the American Museum of Natural History and the Museum of Comparative Zoology, Harvard University. As is generally the case local collections (public) have few representative examples of fossils collected during this period.

PERSONAL OBSERVATIONS

As to the reported size of coral heads by early explorers, they may not have been exaggerated. I have observed coral heads in local quarries that exceed the size of an automobile. One Stromatropoid colony currently exposed at the Falls measures (22) twenty-two feet across.

Standing on one of the large flat shelves of the Falls it is difficult to imagine a free-flowing river, coursing through a series of rapids composed of a fossil sea-bed frozen in time and 3-D to boot. But then some day in the not too distant future, someone will stand in the middle of the Amazon and not quite believe in a continental rainforest.

THE EARLY DAYS CONTINUED....

The Falls were considered to be a navigational hazard. So plans were made to remove it, the falls and several upstream islands were to be quarried below river level. The curb stones of the older sections of Louisville, Kentucky; New Albany, Jeffersonville and Clarksville, Indiana are dimesion stone quarried from the Falls.

In the meantime several canals were driven through the Falls. Quarry operations cintinued until the completion of the McAlpine Dam, which is located to the north and west of the remaining exposure. The dam and associated locks has blocked access to the Falls from the Kentucky shore. Access to the remaining portion of the Falls is from the Indiana shore and at only certain periods of low water, generally in late summer and early fall. The point of access is just below the Penn-Central Railroad bridge and either across the slick algae covered gates of the McAlpine Dam or through the algae covered potholes (a real leg breaker).

The McAlpine Dam and associated locks not only destroyed much of the remaining Falls, it changed the course of the river. The Ohio river prior to dam and lock construction used to flow in such a manner that the Indiana shore was a "cut-bank" in the area of the Falls. Now this has changed and the Indiana shore is a "fill-bank".

Since the construction of the dam (10) ten to (35) thirty-five feet of mud, logs and river trash have been deposited on the Indiana shore and a portion of what used to be the Falls. (see fig. 1-2)

It has been estimated that before the dam was built, it took between (100) one hundred to (150) one hundred and fifty years for the silt laden river water to carve one inch of rock away from a fossil coral head. This of course does not take into account the fragments that will break off the fossil. Some of the large coral heads protrude approximately (1/2) one-half of an inch at present. This somewhat more rapid erosion may be due to an increased silt load in the river.

STATUS OF COLLECTING:

Collecting at the Falls is currently forbidden _ A National Nature Interpretative Center is planned, adjacent to the Falls on the Indiana shore. All privately owned land is being condemned and all "river rats" (indigenous inhabitants - fishermen) are being driven off. Outside of a few approved professionals, no other persons are or will be allowed to remove any rock __ with the exception of the Corps of Engineers.

To my knowledge there have not been any collectors _ amateur or professional who have ever done any wholesale collecting of fossils at the Falls since the quarry operations ceased. This is due in part to the extreme hardness of the enclosing rock and the fact that most of the fossils exposed by past quarry operations are flushed to the rock surface. Knowledgeable collectors hunt their "Falls of the Ohio" fossils from decomposed rocks in the form of a red residual clay that overlies the same rock as found at the Falls. This residual soil is found at local constructions sites, road cuts and quarry sites. The majority of fossils found in these red clays are silicified. Therefore the residual clays contain wonderful preserved corals and other fossils that may be collected without use of a hammer or chisel.

PERSONAL OBSERVATION:

For a time I was actively engaged in the preservation of the Fall of the Ohio; however I resigned when over - zealous justification documents were drawn up by uninformed local naturalists and endorsed by vote-seeking politicians, were printed and forwarded to Washington. These documents singled out amateur fossil collectors with the destruction of the fossil beds at the Falls. One such excerpt reads: "Designation as a national Wildlife area provides Federal protection of the area from vandalism _ such as the hunting and removal of fossils and dumping of refuse". Up until this document and others like it were written and when President Reagan signed the bill designating the area "a wildlife area" in December 1981, the Falls of the Ohio was an abandoned quarry and an open dump. After all by the time the amateur collectors arrived on the scene, the major collections had been gathered, the government's attempt at total removal by quarring had ripped and blasted any remaining fossils, the Indian Mounds were used for flood-wall fill. The river's cource was changed and open dumping was in vogue.

PALEONTOLOGY:

The first corals from the Falls were described by Rafinesque and Clifford in 1820. These first descriptions were vague and one genus containing two species are currently recognized. Some of their descriptions were quite finciful ie.."Resembling a phrygian bonnet upside down" for Zaphrenthis phrygia, and "resembling petrified buffalo horns", for Siphonophrentis (gigantea) elongata. None of the fossils described were illustrated and the type specimens were lost. Troost (1840) described a species of coral from Tennessee, later to be renamed as Pleurodictyum maxium a species common to the Falls. Michelin (1846) described a fossil coral and assigned it to the genus Favosites which was later assigned to the genus Pleurodictyum. Yandell and Schumard (1847) described several corals from the Falls and did not privide any illustrations. D'Orbigny in (1850) described (6) six species of corals from the Falls, without illustrations. It is thought that D'Orbigny's type specimens reside at the School of Mines in Paris. Edwards and Haime (1851) renamed some of D'Orbigny's species and described (7) seven additional species from specimens collected by de Verneuil that were deposited in the School of Mines in Paris. Rominger (1876) included (19) nineteen new species of coral from the Falls in a description of fossil corals of Michigan. Hall (1876) described (4) four species from the Falls. Lyon (1879) described (3) three species of coral from the Louisville Limestone.

Hall (1882) bought a collection of corals from Reverend H. Herzer, a minister from Louisville and described (124) one-hundred and twenty four new corals. Hall (1883) renamed (77) seventy- seven of the former (124), then in (1884) renamed a few more.

Ulrich (1886) named (2) two new species. William J. Davis (1887) published a monograph on Kentucky corals, but only the plates were published. Kindle (1898 - 1899) and (1901) described the Devonian and Silurian stratigrahpy of the Falls) and described the "known" corals. Greene (1898-1906) published a series of papers describing (164) one-hundred and sixty-four species of coral from the Falls. Since Greene was a dealer in geological specimens, the "creation" of new species was in his best interest. Reverend Herzer (1902) described (15) fifteen new species. Beecher (1903) revised (2) two of Davis' species. O'Connell (1914) described several new species of coral. Werner (1932 & 1936) recognized that (17) seventeen of Davis' and Greene's corals were synonymous. Okulitch (1937) described (5) five new specied. Bassler (1937) redescribed (2) two new species. Between (1947 and 1964) Stumm published over twelve papers redescribing most of the coral fauna of the Falls. Amsden (1949) discussed several of Davis' species. Buehler (1955) described the Halystid corals (chain coral). Oliver (1958) redescribed several species of coral from the Falls.

Before Stumm (1964) publication of <u>Silurian and Devonian corals of the Falls of the Ohio</u>, GSA memoir #93, there were between 500 to 750 "recognized" fossil corals from the Falls. Most of the afore mentioned paleontologists and others had little or no communations with one another. some species of coral had been given as many as (20) twenty different names. This utter confusion kept many paleontologists from even attempting to straighten out the mess. This confusion is still a bone of contention and will for years to come. However I have chosen Stumm's work as my preferred reference in dealing with the identification of corals from the Falls.

Stamm has described (67) sixty-seven species of coral from the Louisville Limestone, I have identified (50) fifty of these corals in my collection. Stumm described (147) one-hundred and forty-seven corals from the Jeffersonville Limestone, I have collected (61) sixty-one species. Stumm described (5) five species from the Silvercreek Limestone, I have (3) three, and finally Stumm described (52) fifty-two species of coral from the Beechwood Limestone and I have collected (25) twenty-five .

After about fifteen years of intensive collecting I have managed to identify (139) one hundred and thirty-nine of Stemm's (271) two-hundred and seventy-one corals from the Falls area. (please note the accompanying fossil lists).

This paper is mainly about the coral fauna of the Falls. for those interested in other fossil types such as trilobites, crinoids etc., those groups have received very little attention in the literature. Occasionally in leafing through older publications some plates or illustrations are found. But as yet I have not found a comprehensive publication on the other fossil assembledges that passing statements are made of in the literature. Occasionally when walking about on the Falls of the Ohio traces of trilobites crinoids, cephalopods and large fragments of bony fish plates are seen. There is one area at the Falls that thousands of large gasrtopods (Turloo shumardi) stud the surface, also molds of pelecypods and brachiopods are common in particular layers.

It is my hope that when the Nature Interpretative Center is built , that the goal will be to teach the people of the beauty contained in the rocks and not to dwell on the subject of vandals. But I know in my heart and can almost hear the guides explaining to the school children that vandals armed with hammers and chisels destroyed or nearly so, one of the great wonders of the earth.

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Table I.

Louisville Limestone

Alveolites fibrosus Davis
+ A. louisvillensis Davis
A. undosus Miller
+ Anisophyllum trifurcatum Hall
A. (?) unilargum Hall
+ Arachnophyllum mammillare (Owen)
+ A. pentagonum (Goldfuss)
+ A. quadrangulare (Davis)
+ A. separatum (Ulrich)
+ A. sinemurum (Davis)
+ A. striatum (d'Orbigny)
Asthenophyllum davisi n. sp.
+ A. (?) scitulum (Hall)
+ Astrocerium niagarense (Davis)
+ A. venustum Hall
+ A. hisingeri (Edwards and Haime)
Aulopora precius Hall
A. (?) pygmaea Davis
+ Coenites verticillatus (Winchell and Marcy)
C. sp. A
Cladopora aculeata Davis
C. ordinata Davis
C. (?) menis Davis
C. reticulata Hall
Craterophyllum invaginatum (Davis)
+ Cystihalysites nexus (Davis)
Cystiphyllum granilineatum Hall
C. niagarense (Hall)
+ Dalmanophyllum gainesi (Davis)
D. herzeri (Hall)
Diorychopora tenuis Davis
Entelophyllum eruciforme (Davis)
+ E. rugosum (Smith)
+ E. strictum (Edwards and Haime)
+ Favosites discoideus (Roemer)
+ F. discus Davis
+ F. favosus (Goldfuss)
+ F. niagarensis Hall
+ Halysites louisvillensis n. sp.
+ Heliolites megastoma (McCoy)
+ H. romingeri n. sp.
+ H. subtubulatus (McCoy)
+ Ketophyllum intertrium (Hall)
Kodonophyllum vadum (Hall)
Lamprophyllum niagarense (Davis)
+ Plasmopora elegans (Hall)
P. follis Edwards and Haime
+ Pleurodictyum louisvillensis (Greene)
Propora glabra (Owen)
+ P. papillata (Rominger)
P. puella (Davis)
+ Quepora huronensis (Teichert)
+ Q. louisvillensis n. sp.
Rhabdocyclus scutellus (Davis)
+ Rhizophyllum attenuatum (Lyon)
R. corniculum (Lyon)
+ Romingerella major (Rominger)
Romingeria vannula Davis
+ Schlotheimophyllum fulcratum (Hall)
S. ipomaea (Davis)
?Striatopora huronensis Rominger
+ Streptelasma obliquum (Davis)
+ S. (?) subvesiculare (Hall)
Strombodes shumardi (Edwards and Haime)
+ Thecia minor Rominger
+ Tryplasma mitella (Hall)
+ T. prava (Hall)

+ = Collected

Jeffersonville Limestone (Coral Zone)

Acinophyllum davisi n. sp.
+ Acrophyllum ellipticum Davis
A. oneidaense (Billings)
+ Aemuliophyllum exiguum (Billings)
Alveolites asperus (Rominger)
+ A. constans Davis
+ A. expatiatus (Rominger)
A. minimus Davis
+ A. mordax Davis
A. squamosus Billings
+ A. winchellana (Miller)
+ Aulocystis nobilis (Billings)
+ A. (?) procumbens Davis
Aulopora tubiporoides (Yandell and Shumard)
Bethanyphyllum validum (Hall)
+ Blothrophyllum (?) greeni (Davis)
B. romingeri n. sp.
Calostylis (?) trigemma (Davis)
Cayugaea subcylindrica Stumm
Chonostegites clappi Edwards and Haime
Cladionophyllum cicatriciferum (Davis)
Cladopora acupicta Davis
C. bifurca Davis
C. (?) imbricata Rominger
C. (?) robusta Rominger
Coleophyllum romingeri Hall
+ Compressiphyllum davisana (Miller)
Craterophyllum magnificum (Billings)
Cystiphylloides hispidum (Davis)
+ C. infundibuliformis (Greene)
Drymopora fascicularis Davis
+ Diplochone greenei (Miller)
Disphyllum synaptophylloides n. sp.
Edaphophyllum bifurcatum (Hall)
E. bipartitum (Hall)
Emmonsia amplissima Davis
E. bacula (Davis)
E. convexa (Davis)
+ E. emmonsi (Rominger)
E. epidermata Rominger
+ E. radiciformis (Rominger)
+ E. ramosa (Rominger)
+ E. tuberosa (Rominger)
Favosites arbor Davis
F. biloculi Hall
+ F. clelandi Davis
F. impeditus Davis
F. proximatus Stumm
F. quercus Davis
F. ramulosus Davis
+ Hadrophyllum nettelrothi (Davis)
+ Heliophyllum verticale Hall
Heterophrentis irregularis (Hall)
+ H. (?) nitida (Hall)
+ Hexagonaria cincta (Stainbrook)
+ Homalophyllum fusiformis (Hall)
H. herzeri (Hall)
H. ungulum (Rominger)
Kionelasma coarticum (Hall)
+ K. conspicuum (Hall)
+ K. mammiferum (Hall)
Phymatophyllum multiplicatum (Davis)
Platyaxum foliatum Davis
P. orthosoleniskum (Werner)
P. undosum Davis
Romingeria umbellifera (Billings)
Scenophyllum conigerum (Rominger)
Schlotheimophyllum typicum (Davis)
+ Siphonophrentis elongata (Rafinesque and Clifford)
+ Striatopora bellistriata Greene
+ Syringopora hisingeri Billings
+ S. perelegans Billings
+ Thamnopora limitaris (Rominger)

Speeds Limestone

+ Aulopora sp.
Bordenia knappi (Hall)
+ Hadrophyllum orbignyi Edwards and Haime

Silver Creek Limestone

+ Aulocystis transitorius n. sp.
Pleurodictyum (Procteria) cornu Stumm

Jeffersonville Limestone (Above Coral Zone)

Aulopora edithana Davis
+ Aulacophyllum mutabile Davis
+ A. perlamellosum (Hall)
+ A. pinnatum Hall
+ A. sulcatum (d'Orbigny)
Bethanyphyllum arctifossa (Hall)
B. pocillum (Davis)
+ Blothrophyllum sinuosum Hall
+ B. tripinnatum (Hall)
+ B. trisulcatum (Hall)
Bucanophyllum ohioense (Nicholson)
Chonostegites tabulatus (Edwards and Haime)
Cladopora (?) gracilis Davis
Craterophyllum (?) latiradium (Hall)
+ Cystiphylloides plicatum (Davis)
C. pustulatum (Hall)
Eridophyllum apertum (Hall)
E. coagulatum (Davis)
E. conjunctum (Davis)
+ E. seriale Edwards and Haime
Favosites mundus Davis
F. patellatus n. sp.
+ F. pirum Davis
Heliophyllum denticulatum Hall
+ H. incrassatum Hall
+ H. latericrescens Hall
+ H. venatum Hall
+ Heterophrentis duplicata (Hall)
+ H. inflata (Hall)
H. rafinesqui (Edwards and Haime)
+ Hexagonaria bella (Davis)
H. curta Stumm
H. ovoidea (Davis)
H. partita (Greene)
H. prisma (Lang and Smith)
+ Pleurodictyum cylindricum (Michelin)
+ P. maximum (Troost)
P. (Procteria) michelinoidea (Davis)
P. (Procteria) papillosa (Davis)
P. (Procteria) spiculata (Greene)
Romingeria commutata Beecher
R. fasciculata Davis
R. uva Davis
+ Siphonophrentis planima (Hall)
+ S. yandelli (Edwards and Haime)
+ S. elongata (Rafinesque and Clifford)
+ Skoliophyllum squamosum (Nicholson)
+ Stereolasma (?) exile (Davis)
S. parvulum (Davis)
Striatopora (?) alba Davis
+ S. cavernosa Rominger
+ Trachypora tuberculata n. sp.
Zaphrenthis aequus (Hall)
+ Z. phrygia Rafinesque and Clifford

Jeffersonville Limestone (Undifferentiated)

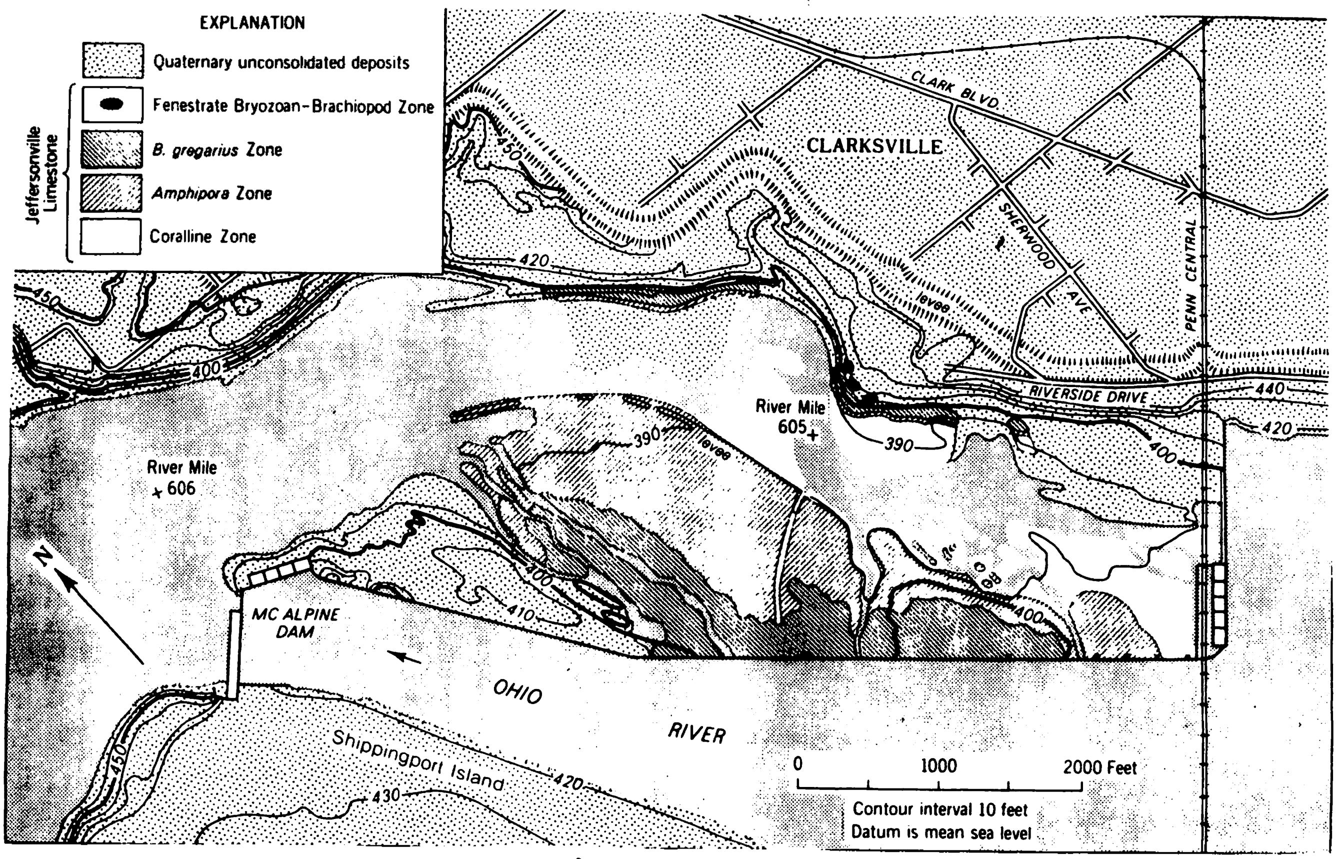
Acrophyllum rugosum Greene
Amplexiphyllum cruciforme (Hall)
A. (?) simplex (Hall)
+ A. tenue (Hall)
Aulocystis (?) incrustans (Davis)
Bethanyphyllum depressum (Hall)
B. vesiculatum (Hall)
Billingsastrea yandelli (Rominger)
Blothrophyllum bellicinctum Greene
+ Cylindrophyllum compactum (Hall)
Cystiphylloides nanum (Hall)
C. quadrangulare (Hall)
C. tenuiradium (Hall)
Disphyllum cohaerens (Hall)
+ Emmonsia cymosa (Davis)
+ Heliophyllum agassizi Greene
Heterophrentis annulata (Hall)
+ H. cyathiformis (Hall)
+ H. ovalis (Hall)
H. trisutura (Hall)
+ Hexagonaria ponderosa Stumm

Table 2.

Beechwood Limestone

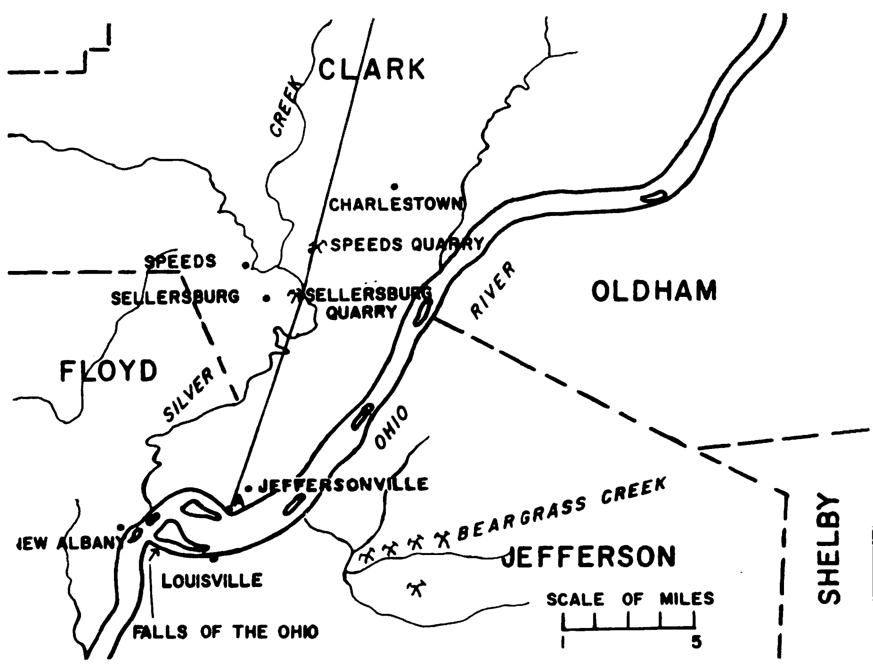
Acrophyllum clarki Davis
A. conigerum (Greene)
Alveolites goldfussi Billings
A. sp. A
Aulocystis auloporoidea (Davis)
A. jacksoni (Grabau)
+ *A. transitorius* n. sp.
Bethanyphyllum prateriforme (Hall)
+ *B. robustum* (Hall)
+ *Blothrophyllum zaphrentiforme* Davis
+ *Cladopora gulielmi* Davis
Craterophyllum adnascens (Greene)
+ *Cystiphylloides americanum* (Edwards and Haime)
+ *C. crassatum* (Greene)
+ *Edaphophyllum* (?) *laciniatum* (Greene)
Emmonsia arbuscula (Hall)
+ *E. eximia* (Davis)
+ *Eridophyllum archiaci* (Billings)
E. tumidulum (Hall)
Favosites clausus Rominger
F. hamiltoniae Hall
F. placenta Rominger
F. rotundituba Davis
+ *F. turbinatus* Billings
Hallia (?) *strigata* (Greene)
+ *Heliophyllum alternatum* Hall
H. ethelanum (Davis)
H. gurleyi Greene
+ *H. halli* Edwards and Haime
+ *H. infundibulum* Hall
+ *H. insigne* (Davis)
+ *H. tenuiseptatum* Billings
Heterophrentis concava (Hall)
+ *H. foliata* (Hall)
+ *H. simplex* (Hall)
H. subcompressa (Hall)
+ *Odontophyllum convergens* (Hall)
O. patellatum (Holmes)
O. tornatum (Davis)
Phymatophyllum nanum (Davis)
Platyaxum frondosum (Nicholson)
+ *Pleurodictyum insigne* (Rominger)
+ *P. planum* (Davis)
P. wardi Greene
Scenophyllum (?) *coniferum* (Greene)
+ *Siphonophrentis halli* (Edwards and Haime)
Stereolasma gallicalcar (Davis)
S. rectum (Hall)
+ *Striatopora* sp. A
+ *Trachypora alternans* (Rominger)
+ *T. vermiculosa* (Lesueur)
+ *Zaphrenthis* (?) *amplexiformis* Greene

+ = collected



U.S. Army Corps of Engineers - Unpublished (1964)

Figure 2



General Location (Stumm 1964)

Figure 3

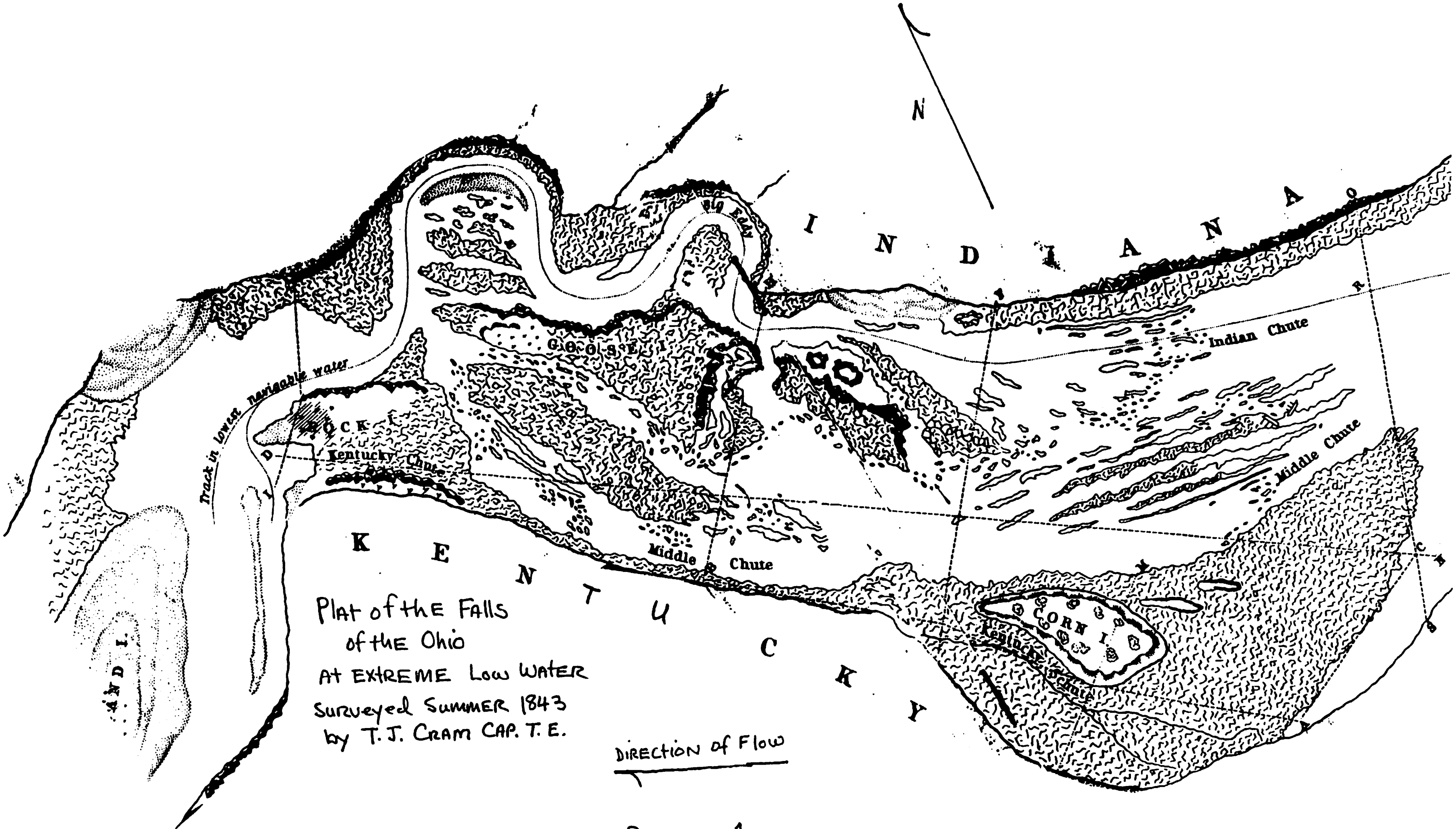

N
I N D I A N A
K E N T U C K Y
Big Eddy
GOOSE I.
ROCK
Kentucky Chute
Indian Chute
Middle Chute
Middle Chute
CORN I.
Kentucky Chute
Track in lowest navigable water
Plat of the Falls
of the Ohio
At EXTREME Low WATER
Surveyed Summer 1843
by T. J. Cram Cap. T. E.
Direction of Flow

figure 1

SOFT-BODIED FOSSILS FROM THE SILURIAN OF WISCONSIN

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Introduction

Deposits that contain exceptional fossils are called *Fossil-Lagerstätten* (singular, *Lagerstätte*). *Lagerstätte* is an old German mining term referring to a rich body of ore mineral. Two German paleontologists, Weigelt and Seilacher, applied this term to the fossil record, using it to describe a deposit that contains a wealth of paleontological information. Borrowing again from mining terminology, a *Lagerstätte* is a fossil bonanza or "mother lode" of fossils. *Fossil-Lagerstätten* are more than just a source of beautiful fossils, however. They provide us with a unique opportunity to gain important but otherwise unattainable knowledge about the history of life on Earth.

There are two types of *Fossil-Lagerstätten*: Concentration (*Konzentrat*) and Conservation (*Konservat*). Concentration *Lagerstätten* are deposits that contain vast numbers of fossil specimens, typically shells, bones, or other hard parts. The fossils are not necessarily well preserved, but they are numerous. The jumble of dinosaur bones in the Jurassic rocks at Dinosaur National Monument is an example of a Concentration *Lagerstätte*.

In contrast, Conservation *Lagerstätten* contain extraordinary fossils that preserve soft parts such as muscle and skin or chitinous exoskeletons, or they contain articulated skeletons. Conservation *Lagerstätten* are by far the rarer of the two, yet they include some of the most famous fossil beds known. The Burgess Shale and Mazon Creek *Lagerstätten* are examples where soft-bodied fossils, such as jellyfish and arthropods are preserved. The complete articulated crinoid specimens at Crawfordsville, Indiana, are an example of articulated fossil preservation.

Conservation *Lagerstätten* are especially important in the geologic record for several reasons. 1) They provide us with the only body-fossil evidence for organisms without hard parts or with poorly mineralized exoskeletons. For example, in most rocks evidence of worms comes mostly from their trace-fossils or tiny phosphatic jaws. In some *Lagerstätten*, however, the actual soft bodies of the worms are preserved. Arthropod fossils other than trilobites are uncommon outside of *Lagerstätten* because most have exoskeletons made of chitin, an organic material less likely preserved than the calcium carbonate shells of brachiopods and clams.

2) We know that in today's oceans only about 30% of marine organisms have hard parts that would likely be preserved as fossils; the majority of organisms are soft-bodied. Conservation *Lagerstätten* thus give us a more realistic view of the variety of ancient life and help us to better understand the history of Earth.

3) These deposits show us what the soft tissues of organisms that we otherwise know only from hard parts look like. For example, the delicate limbs of trilobites or the tentacles of cephalopods may be preserved.

Many hazards await the body of an organism after death. It can be scavenged by predators, decomposed by microbes, tossed about and disarticulated by currents, or scattered by animals crawling on and through the sediment. The fossil record favors those organisms with readily preservable hard parts. Soft parts, typically the most tasty and easily decayed, are rarely fossilized. In order for articulated skeletons or soft parts to be preserved, the potential fossil must be buried by sediment soon after death and be able to escape disturbance by other organisms or by water movement. The environment where the organism comes to rest must be inhospitable to living animals that would churn up the sediment or eat the carcass, and currents and waves must be restricted so that the sediment is not moved about and the carcass washed away. These are special circumstances.

Consequently, only a few deposits in the entire world contain soft-bodied fossils. Perhaps the most famous and most important of these is in the Middle Cambrian Burgess Shale of British

Columbia, Canada. This large *Lagerstätte* is especially significant because its fossils show that many different types of invertebrate animals had evolved very soon after the first appearance of multicellular animals.

Unfortunately, few Conservation *Lagerstätten* are known in rocks from Middle Cambrian to Lower Devonian age, a time span of 100 million years. The most diverse group of soft-bodied organisms presently known from this long gap comes from Lower Silurian rocks of Wisconsin (Mikulic, et al., 1985a, b).

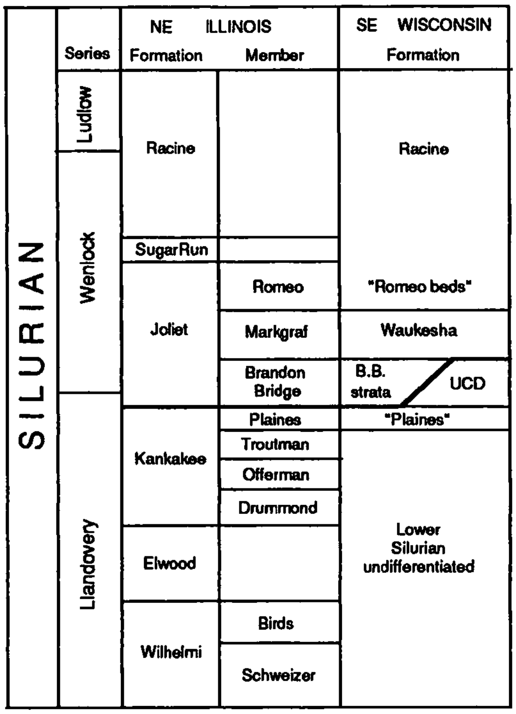

Figure 1. Stratigraphic column for Silurian rocks in northeastern Illinois and southeastern Wisconsin. Wisconsin terminology is undergoing revision and some names are informal. B. B. = Brandon Bridge, UCD = unnamed cherty dolomite.

Geologic Setting of the Waukesha *Lagerstätte*

This *Lagerstätte* is found in the Lower Silurian Brandon Bridge beds (Fig. 1). This exceptional deposit is present in a single quarry in Waukesha County, Wisconsin. Soft-bodied fossils occur only in a 12 cm-thick layer of very finely laminated, gray to black, shaley dolomite. These laminated sediments are found at the foot of an ancient rock cliff about 8 meters high (now buried beneath other rock strata). The fossiliferous bed runs only about 100 meters across the quarry parallel to the cliff and extends only a few meters away from the cliff. Further from the cliff, nonlaminated sediments more like the typical green and pink Brandon Bridge strata in the rest of southeastern Wisconsin and northeastern Illinois.

This part of North America was located about 20° south of the equator at that time. The climate was tropical and probably a little humid, similar to conditions in the Bahamas today. The cliff and other minor troughlike topography at its base was probably formed by subaerial weathering during a period of lowered sea level before the Brandon Bridge was deposited.

When sea levels rose again, much of the Brandon Bridge sediments were laid down under intertidal or very shallow subtidal conditions. The *Lagerstätte* was deposited only at the foot of the cliff where water circulation was restricted. Restricted water circulation created quiet-water stagnant conditions with oxygen levels so low that animals could not survive. The two required conditions (quiet water and exclusion of animal disturbance) had been met, and the potential for extraordinary fossil preservation existed.

The *Lagerstätte* Biota

Fossils in the *Lagerstätte* are not confined to any specific laminae or layers. They are rare and widely scattered throughout the bed. For this and several other reasons they are very difficult to find and prepare. Most specimens have very little or no relief, so the rock does not split naturally along the fossils. Fossils are difficult to see in vertical section because of this low relief. Also, when the rock was altered to dolomite, the laminae were more or less fused together, causing the rock to fracture across instead of along bedding planes.

Arthropods dominate the Waukesha *Lagerstätte*. Most are small, only a few centimeters long, but some reach nearly 10 cm in length. Fossils may be preserved in several ways. Calcite in well-mineralized exoskeletons, such as those of trilobites, was dissolved soon after death. Because of this, surface detail is poorly preserved and specimens are very compacted. Animals with more organic exoskeletons are also very compacted, and some are preserved only as a thin organic film. Detail on some arthropods, however, is exquisitely preserved by diagenetic phosphate minerals, with even lenses of tiny compound eyes visible.

Trilobites, represented by thirteen genera, are the most numerous and varied of the arthropods (Table 1). The most common trilobite is an undescribed dalmanitid, specimens of which cover some bedding planes. Because of early shell dissolution and compaction identification at the species, and even genus, level is difficult.

Trilobitomorpha	**Chelicerata**
Trilobita	xiphosure
dalmanitid	
Stenopareia	
Meroperix	**Uniramia**
Leonaspis	myriapod
Scotoharpes	
Arctinurus	
calymenids	**Crustacea**
phacopids	phyllocariids
cheirurids	ostracods
encrinurines	thylacocephalan
proetids	?remipede or branchiopod
3 indeterminate arthropods	

Table 1. Arthropods present in the Waukesha *Lagerstätte*.

Many of the trilobites and other arthropods are complete, articulated, and outstretched. However, the limbs and other soft parts of trilobites are not preserved and hypostomes are very rare and not found in place. This suggests that the trilobite specimens are molted exoskeletons and not the remains of dead carcasses.

Besides trilobites, all three other major groups of arthropods occur in the Waukesha *Lagerstätte* (Table 1). Chelicerates (including horseshoe crabs, spiders and eurypterids) are distinguished by the presence of chelae on certain appendages and by the absence of antennae. The Waukesha chelicerate is a xiphosure, an early relative of the horseshoe crab (Fig. 2). It is important because it is the oldest known fossil xiphosure with preserved chelae. Only one other Paleozoic example is known from the Lower Devonian Hunsrück Slate of Germany. Interestingly, no eurypterid specimens have been found at Waukesha, although they are quite common in Upper Silurian *Lagerstätten* elsewhere.

Crustaceans (shrimps, crabs, lobsters and their relatives) are the most common and diverse of the nontrilobite arthropods in the Waukesha *Lagerstätte*. Crustaceans are distinguished from other arthropods by the presence of antennae and by branched and specialized appendages used in feeding and locomotion. Ostracods are the most numerous crustaceans at Waukesha, occurring in great numbers on some bedding planes. Only the hinged bivalved carapaces of these are preserved, and these are usually articulated but opened in a butterfly position. Their appendages are not preserved, suggesting that these also are molts. Two species of phyllocariid crustaceans, primitive relatives of lobsters and shrimp, also occur at Waukesha.

Two other possible crustacean taxa are present. The rarer of these may be a thylacocephalan, a type of crustacean only recently described. These have a bivalved carapace that covers the entire body and all but the very tips of the appendages. At least three of the appendages at the front are spiny and seem to be adapted for seizing prey. Large compound eyes help make

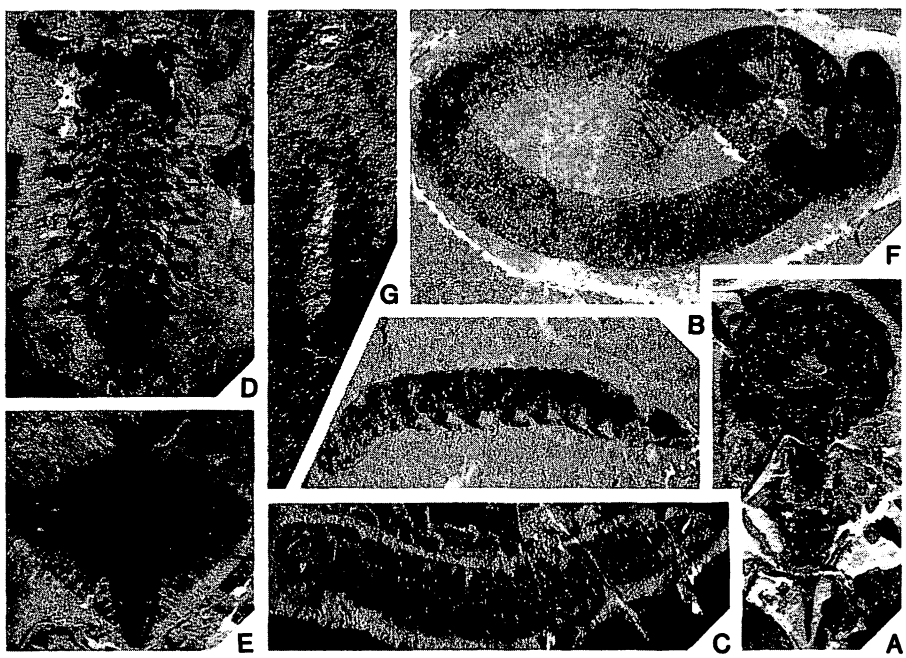

Figure 2. Representative soft-bodied and weakly mineralized animals in the Waukesha *Lagerstätte* biota. A) Xiphosuran chelicerate, x0.9. B) Myriapod-like uniramian, x2.1. C) Elongate indeterminate arthropod, x0.9. D) ?Remipede or branchiopod crustacean, x2.1. E) Indeterminate arthropod with unusual ?carapace, x1.3. F) ?Leech, x1.2. G) Conodont animal, elements (ap) at front, with elongate segmented body (tr), x4. (From Mikulic, et al., 1985a)

this animal a well-equipped predator. If these are thylacocephalans, it would extend their geologic range back 40 million years from the Early Devonian. Additionally, this is the only known Paleozoic example preserving soft parts such as limbs and eyes.

The most common and best preserved of the unusual crustaceans at Waukesha resembles both branchiopods and remipedes (Fig. 2). The latter group was only recently discovered in freshwater tropical caves and lacks any other known fossil record. The Waukesha specimens have two large anterior grasping appendages and large compound eyes, suggesting this arthropod was a formidable predator.

Uniramian arthropods have unbranched appendages. The uniramian at Waukesha is probably a myriapod, a group so named because of their many legs (Fig. 2). It has an elongate body with 11 segments, each with a pair of limbs. Modern uniramians (centipedes, millipedes and insects) are nearly all terrestrial. The group is thought to have had an aquatic, possibly marine, ancestor. The oldest other fossil myriapod is known from terrestrial/freshwater Upper Silurian deposits of Scotland. The Waukesha specimens, therefore, may prove a marine origin for the group.

Two other arthropod taxa at Waukesha cannot yet be assigned to any known group. One of these has an elongate segmented body with a short shield-covered head with at least one compound eye and several pairs of jointed limbs including possible antennae (Fig. 2). The limbs along the rest of the body look like short little lobes. This animal looks something like an extinct branchiopod crustacean otherwise known only from the Jurassic.

The most unusual of these arthropods has a segmented body that is partially covered by two triangular or circular structures resembling a bivalved carapace (Fig.2). The appendages or eyes of this arthropod have not yet been discovered. Typically whole specimens of this taxon are only 1-2 cm long, but a few isolated specimens of the possible carapace are as much as 20 cm wide.

Worms, represented by at least four taxa, are characteristic of the Waukesha biota. Annelid worms are the most common as body-fossils. The tiny phosphatic jaws of polychaete worms have been found, but their soft parts have not. The largest and most interesting worm, but unfortunately one of the rarest, has a ringlike structure at one end that looks like the sucker of a modern leech (Fig. 2). This would be the oldest leech in the fossil record, and it would extend the range of Class Hirudinea back more than 250 million years from the Upper Jurassic. Many worms at Waukesha are preserved in a coiled position. The worms may have rolled up to conserve energy under oxygen-deficient conditions, but died before oxygen levels rose.

One of the least complete and most poorly preserved fossils in the Waukesha *Lagerstätte* is also one of the most important because it is probably a conodont animal (Fig. 2). Tiny toothlike conodont elements are made of phosphate minerals and are easily preserved. They are abundant in Cambrian through Triassic rocks around the world and are important for dating rocks. In contrast, the soft parts of the animal that these elements belong to are poorly known. We are not certain just what kind of animal conodonts were or how they are related to other animals. Some paleontologists believe they may be related to chaetognath worms, whereas others think they are chordates. The soft parts are important to interpreting the animal's lifestyle and relationship to other animals. Unfortunately, definite specimens of the soft-bodied conodont animal have been found at only one locality in lower Carboniferous rocks of Scotland. The Scottish specimens have an elongate, segmented, wormlike body with fins, and the elements are arranged symmetrically at the anterior of the body. The single incomplete and poorly preserved Waukesha specimen resembles the younger Scottish specimens in general appearance. With luck, additional specimens will be discovered at Waukesha that may solve the mystery surrounding this animal.

Certain organisms are absent from the Waukesha *Lagerstätte*. Shelled organisms (e.g., brachiopods, corals, molluscs, and crinoids) found in abundance in Silurian rocks elsewhere are either extremely rare or totally absent in the Waukesha *Lagerstätte* (Fig. 3). Organisms that sat on or were attached to the seafloor are generally lacking. The vast majority of organisms preserved at Waukesha are arthropods or worms that had active, free-living lifestyles.

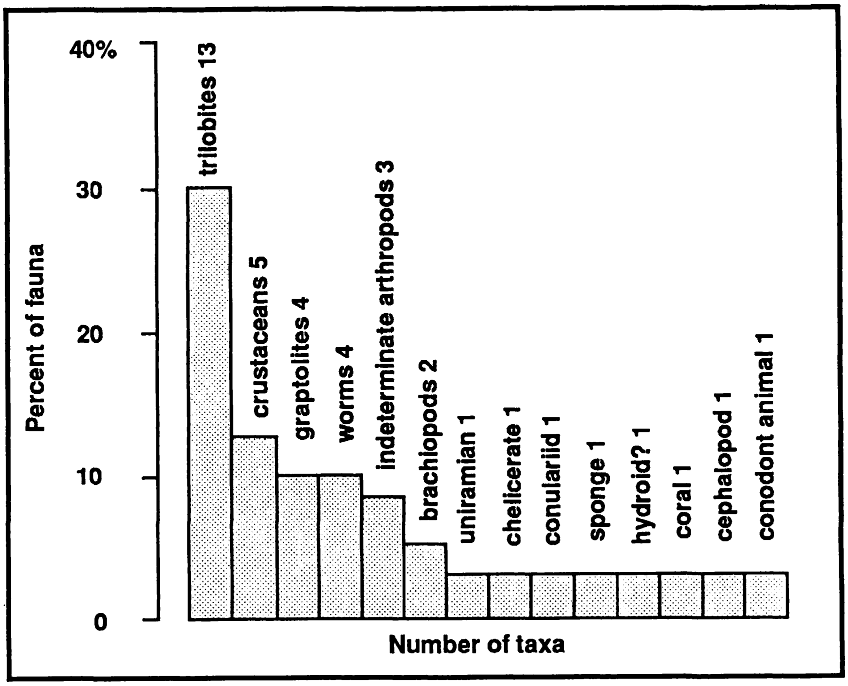

Figure 3. Bar graph showing percentage composition of Waukesha *Lagerstätte* fauna. The coral, cephalopod, brachiopods, and conodont animal are represented by only one or two specimens each.

How was the Waukesha *Lagerstätte* Formed?

The Waukesha *Lagerstätte* probably was deposited in very shallow water. These sediments were deposited at the beginning of rise in sea level following a period of emergence. There are abundant algal bodies in parts of the *Lagerstätte itself and* algal mounds are present in the vicinity. Algae requires sunlight to photosynthesize and, therefore, the water could not have been very deep or choked with sediment. In fact, the water was so shallow before and after deposition of the *Lagerstätte* that in places it temporarily dried up and mudcracks formed. The adjacent cliff probably restricted water circulation enough to cause stagnant oxygen-deficient conditions. The cliff also may have acted as a sediment trap, where fine-grained sediments and lightweight organic debris were washed in and concentrated (Fig. 4).

Poorly oxygenated conditions are suggested by several lines of evidence. Laminations are preserved only if organisms don't disturb, or bioturbate, the sediment. Under normal conditions, as animals plow through the sediment in search of food they produce a churned-up, nonlaminated mixture. Absence of bioturbation means that organisms were not living in the sediment. The environment may have been lethal because there was little or no oxygen in the sediment or water column. The absence of stationary or attached seafloor-dwelling organisms, which are even more sensitive to environmental quality because they can't just get up and leave, also indicates unfavorable conditions. Coiling of worms is thought to be a reaction to low oxygen levels also.

How do we explain the presence of any fossils in the *Lagerstätte* then if conditions were so unfavorable that little could live at the site? As previously mentioned, arthropods dominate the biota. Unlike the worms, which may be coiled, none of the arthropods are enrolled in a defensive position. Delicate limbs are missing from many arthropod specimens. Some arthropods, such as

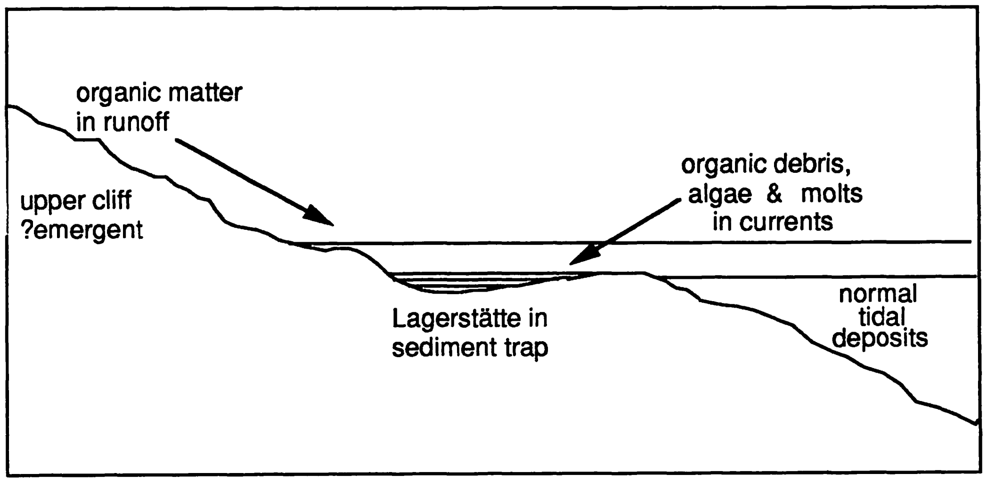

Figure 4. Diagram showing how Waukesha *Lagerstätte* formed. (After Kluessendorf, 1990)

the trilobites and ostracods, are commonly disarticulated, and specimens of a particular species may be size-sorted on individual bedding planes. In addition, evidence for animal activity such as trackways or trails like the famous "death march" trackways of horseshoe crabs in the Solenhofen Limestone, is absent from the Waukesha *Lagerstätte*. These factors suggest that most of the arthropods at Waukesha are molted exoskeletons, not carcasses of dead individuals. Molted exoskeletons are lightweight and easily transported by even gentle currents into sediment traps. The worms, which had lightweight bodies even while alive, may have been transported to the site while living. This would explain their coiling in response to the inhospitable environment. Most shelled organisms, such as brachiopods, were too heavy to transport after death, and while alive, most were attached to the seafloor and not easily washed away. Therefore, most of the animals present in the *Lagerstätte* did not live in the area where they were buried but were washed into the sediment trap.

Summary

Conservation *Fossil—Lagerstätten* are important because they: 1) preserve organisms unknown to science including some that are so unusual they are difficult to place into major biological groupings (e.g., the tully monster from the Pennsylvanian of Illinois); 2) provide clues to the true diversity of ancient life by preserving soft-bodied organisms that otherwise are not found as fossils; and 3) help us to understand the sequence of events in the history of life on Earth. In addition, the Waukesha *Lagerstätte* has extended the known geologic range of several groups, some by nearly 200 million year. It also has yielded the only known North American examples of many soft-bodied taxa.

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THE LEISEY SHELL PIT

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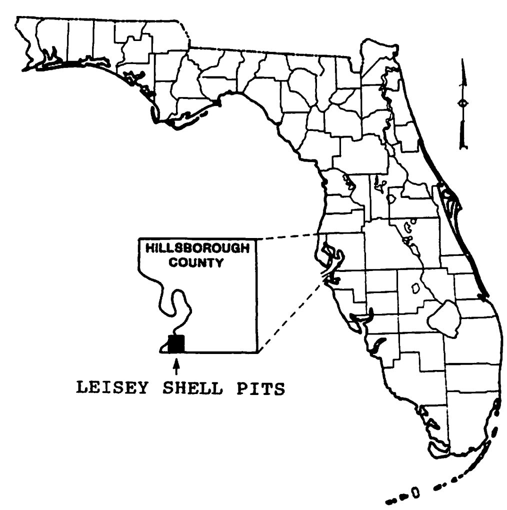
The state of Florida has long been noted for the incredible diversity of vertebrate fossils found there. This wealth of vertebrate fossils is exemplified by the discovery made at the Leisey Shell Pit in Ruskin, Florida in 1983 by Frank Garcia. Ruskin is located in Hillsborough county, 30 miles north of Sarasota and 25 miles south of Tampa. Although numerous shell pits in Florida yield thousands of tons of shells and sand for use in road construction, they rarely warrant an extensive scientific dig such as the one that took place at the Leisey Shell Pit.

Frank Garcia, a noted amateur paleontologist, was collecting at the Leisey Shell Pit when he noticed that one particular cut showed some very encouraging signs of vertebrate material. Although intrigued by the cut, Frank had to leave on a scheduled trip to the Nebraska Badlands. Upon returning from this trip on a Sunday night, he was still thinking of the promising new cut. And on Monday, June 27th, 1983 Frank returned to the pit. Fortunately the dragline operator had left on vacation the previous Friday just after exposing the rich cache Frank had been hoping for. Because of this, Frank was undisturbed by operating machinery while exploring the cut. He was overwhelmed with what he found that day. Immediately he spoke with the Leisey management on the importance of the discovery, and requested them to alter digging plans to preserve the site. They also were convinced of the importance of the find and made excavation of the site possible.



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In 1983 a portion of the area was excavated by Frank Garcia and others. Several thousand specimens were donated to the Florida Museum of Natural History in Gainesville. In April of 1984 the area was prepared in a simple grid fashion and marked for proper scientific excavation. The Tampa Bay Mineral and Science Club supported the excavation with both volunteers and the raising of funds. The Museum of Florida paleontologists and Frank took measurements and marked each major fossil for identification. The Leisey Corp. not only rerouted dragline operations but provided personnel, equipment, supplies, and monetary support. All fossils recovered now reside in the Vertebrate Paleontology Collection of the Florida Museum of Natural History.

The opportunity for amateur paleontologists to help with such an important discovery was a rare and exciting adventure. Almost two hundred volunteers learned field techniques and enjoyed the thrill of being part of re-writing paleontological history. The success of the dig is greatly due to the volunteers donating hundreds of hours to help excavate the Leisey site. Without their help and dedication only a fraction of the fossils would have been recovered. The site excavated in 1983-1984 is acclaimed as being the richest Pleistocene fossil site in North America.

According to the Florida Museum of Natural History, the age of the site is approximately 1.5 million years old. This was determined by using mammalian taxa as biostratigraphic indicators, placing the Leisey site in the pre-late Irvingtonian age. Research by the Florida Museum indicated that a sub tropical climate existed at that time (similar to present time) due to the fossilized presence of mangrove roots and sabal palm seeds. It is thought that the coastal plain of Florida was a woodland-savanna environment which could support a numerous variety of fauna. The fossils were deposited in a slow moving river which appeared to have emptied into a protective bay composed primarily of mud and shells. This would account for no articulated skeletons being found, but rather a disassociated array of fossils from different animals possibly caused from carcasses floating downstream.

Even though the original site is no longer in existence, a different part of the shell pit is still producing incredible fossil treasures, without the significant fossil concentrations that were present at the original site. Due to the notoriety of the shell pit, the Leisey Corp. has restricted fossil hunting by individuals. However the company is aware of the importance the shell pit has provided science, and has allowed organized field trips by the Tampa Bay Fossil Club, the Museum of Science and Industry, and other school and scouting organizations to visit the shell pit.

The following pages list and illustrate some of the animals found at the 1983-1984 site plus some animals discovered at the most recent Leisey site. Amateurs are still donating important fossil finds and expanding Florida Museums ongoing research of the Leisey epic. Unfortunately once shell pits are exhausted, they are flooded and reclaimed back to a natural state. Such is the fate of the famous Leisey site, which will be flooded some time in the near future.

LEISEY SHELL PIT FAUNA

Class Mammalia

Order Artiodactyla
Hemiauchenia macrocephala (long-legged llama)
Mylohyus nasutus (forest peccary)
Odocoileus virginianus (white-tailed deer)
Paleolama (short-legged llama)

Order Carnivora
Arctodus pristinus (short-faced bear)
Canis armbrusteri (wolf-sized dog)
Canis edwardii (coyote-sized dog)
Felis rufus (bob cat)
Homotherium (dirk-toothed cat)
Lutra (otter)
Miracinonyx inexpectus (cheetah)
Monachus (monk seal)
Mustela frenata (long-tailed weasel)
Panthera onca (jaquar)
Procyon (raccoon)
Smilodon gracilis (gracile sabre-toothed cat, the only complete skull ever found in North America was discovered at Leisey's 1984 excavation)
Urocyon (grey fox)

Order Cetacea
Mysticeti (baleen whale)
Stenella (spotted or spinner dolphin)

Order Edentata
Dasypus bellus (beautiful armadillo, approx. 2 ft. tall)
Eremotherium (giant ground sloth, approx. 15-20 ft. tall)
Glossotherium harlani (Harlan's ground sloth, approx. 8-10 ft. tall)
Holmesina floridanus (giant armadillo, approx. 4 ft. tall)
Nothrotheriops (Shasta's ground sloth, approx. 5-6 ft. tall)
minature glyptodont (this new species will be named in an upcoming publication by the Florida Museum of Natural History)
* see references

Order Lagomorpha
Lepus (jack rabbit)
Sylvilagus (cotton tail rabbit)

Order Perissodactyla
Equus fraternus (large-sized horse, a species poorly known elsewhere that is well represented at the Leisey site)

Equus hemionus (new species common at Leisey but rare elsewhere, medium-sized slender-legged horse)
Equus leidyi (stout-legged horse)
Tapirus haysii (giant Pleistocene tapir)

Order Proboscidea
Cuvieronius (gomphothere, the rarest of the three elephants found at Leisey's)
Mammut americanum (american mastodon)
Mammuthus (imperial mammoth)

Order Rodentia
Castoroides ohioensis (giant beaver, approx. 8 ft. tall)
Geomys pinetis (southeastern pocket gopher)
Hydrochoerus (aquatic capybara)
Microtus (meadow vole)
Sigmodon libitinus (extinct cotton rat)

Order Sirenia
Trichechus manatus (west indian manatee)

Class Chondrichthyes

Order Batoidea
Dasyatis (sting ray)
Myliobatis (eagle ray)
Pristis (saw fish)

Order Selachii
Carcharhinus leucas (bull shark, the most common shark teeth found at Leisey's)
Carcharodon carcharias (great white shark, nearly identical to the present day species)
Galeocerdo cuvieri (tiger shark)
Ginglymostoma cirratum (nurse shark)
Hemipristis serra (snaggle-toothed shark)
Isurus hastalis (extinct mako shark)
Negaprion brevirostris (lemon shark)
Odontaspis taurus (sand shark)
Rhizoprionodon terraenovae (sharp-nosed shark)

Class Osteichthyes

Order Elopiformes
Megalops atlanticus (tarpon)

Order Perciformes
Archosargus (sheep head)
Caranx hippos (jack crevalle)
Centropomus (snook)
Labridae (wrasse)

Lagodon rhomboides (pin fish)
Lepomis (sun fish)
Mugil (mullet)
Pogonias cromis (drum fish)
Sphyraena barracuda

Order Semionotiformes
Atractosteus spatula (alligator gar, it's fish scales were the most commonly found vertebrate remains at Leisey's)
Lepisosteus (common gar)

Order Siluriformes
Ictaluras (cat fish)

Order Tetraodontiformes
Balistes (trigger fish)
Diodon (porcupine fish)

Class Reptilia

Order Crocodilia
Alligator mississipiensis

Order Suamata, Suborder Serpentes
Agkistrodon piscivorous (water moccasin)
Coluber (racer snake)
Crotalus adamanteus (rattle snake)
Elaphe (rat snake)
Nerodia (water snake)

Order Testudines
Apalone ferox (soft shell turtle)
Chelonia midas (green sea turtle)
Geochelone crassiscutata (giant land tortoise)
Gopherus polyphemus (gopher tortoise)
Kinosternon (mud turtle)
Macroclemys temmincki (alligator snapping turtle)
Terrapene carolina (box turtle, complete carapace and plastron were found of this species of turtle at Leisey's)
Trachemys scripta (slider turtle)

Class Amphibia

Order Anura
Bufo terrestris (toad)
Rana (pond frog)

Order Urodela
Siren (salamander like amphibian)

Class Aves

Order Ciconiiformes

Ajaia (spoonbill, new species to be named, *see references)
Eudocimus (ibis, new species to be named, *see references)
Phoeicopterus (flamingo, 2 species were found at Leisey's and will be listed in an upcoming publication)

Order Falconiformes

Gymnogyps kofordi (extinct condor, approx. 10-12 ft. wing span)
Teratornis incrediblis (teratorn, extinct vulture like scavenger with an approx. wing span of 15 ft.)

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A special thanks to Frank Garcia for information on the discovery of the famous Leisey site and Gary Morgan for his help on providing the common names of the Leisey fauna.

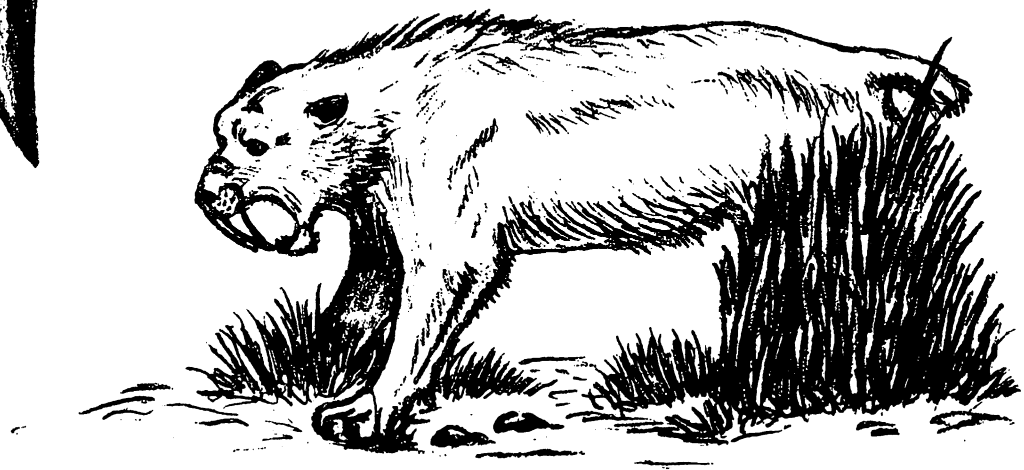
The PAPERS IN FLORIDA PALEONTOLOGY are available through the Florida Paleontological Society Inc. For more information write to the following...

Anita Brown
Florida Paleontological Society Inc.
Florida Museum of Natural History
University of Florida
Gainesville, FL 32611 USA

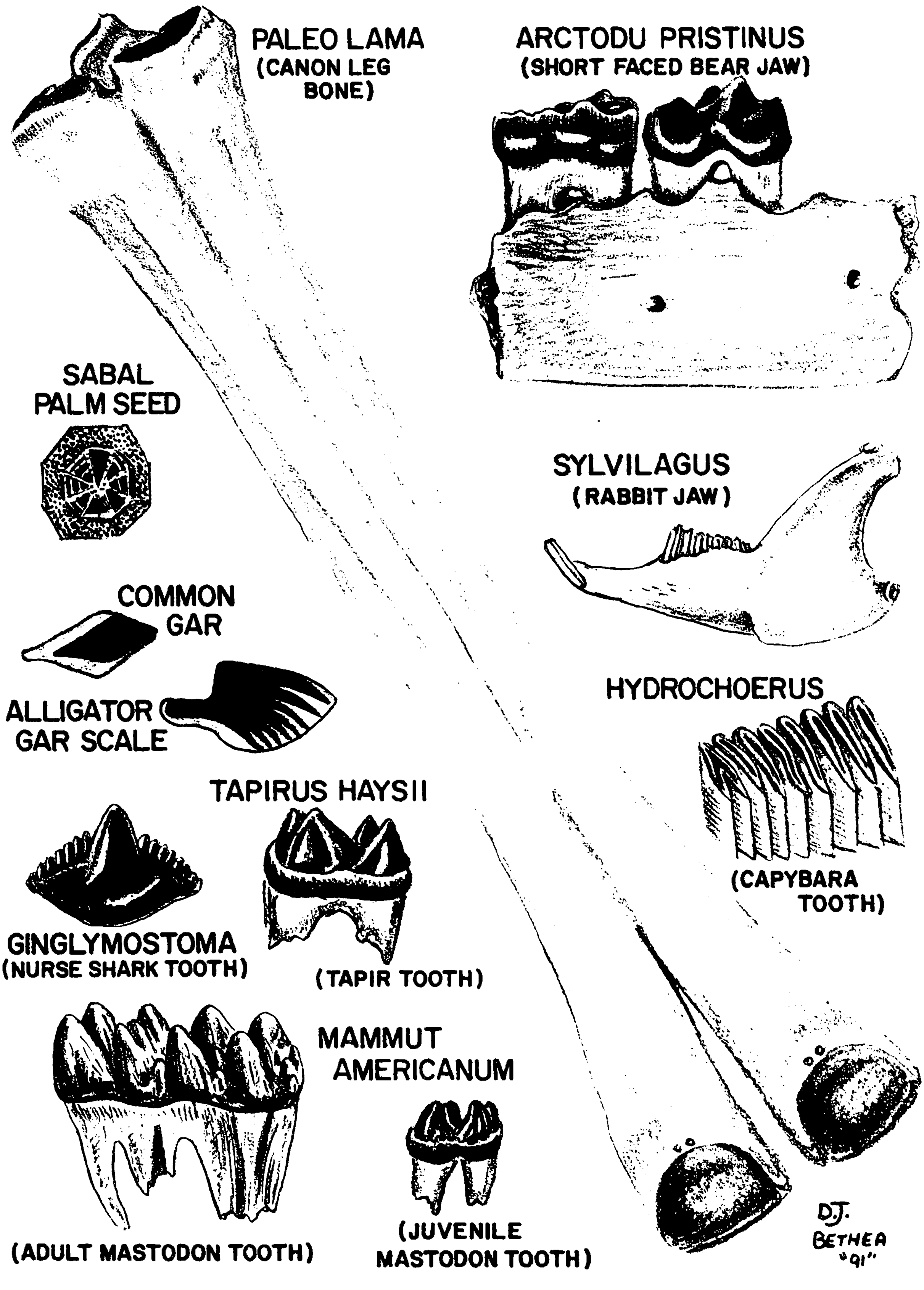
There is an expected publication due to be released on the geology and paleontology of the Leisey Shell Pit this summer. It will be the most comprehensive publication to date on the Leisey site. This combined effort of many specialists will be approximately 250 to 300 pages in length. The new species which were discovered at Leisey's will be named in this upcoming publication. For more information write to the following...

Publication Office
Florida Museum of Natural History
University of Florida
Gainesville, FL 32611 USA

SMILODON GRACILIS
(SABRE TOOTHED CAT)



CASTOROIDES OHIOENSIS
(GIANT BEAVER – LOWER JAW)


PALEO LAMA
(CANON LEG BONE)
ARCTODU PRISTINUS
(SHORT FACED BEAR JAW)
SABAL
PALM SEED
SYLVILAGUS
(RABBIT JAW)
COMMON
GAR
ALLIGATOR
GAR SCALE
HYDROCHOERUS
TAPIRUS HAYSII
(CAPYBARA
TOOTH)
GINGLYMOSTOMA
(NURSE SHARK TOOTH)
(TAPIR TOOTH)
MAMMUT
AMERICANUM
(ADULT MASTODON TOOTH)
(JUVENILE
MASTODON TOOTH)
D.J.
BETHEA
"91"

MISSISSIPPIAN - WAVERLY GROUP FOSSIL BEARING FORMATIONS NORTH CENTRAL OHIO

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The Mississippian rocks of Ohio are exposed in a wide belt from the Ohio River in the south, to the vicinity of Lake Erie in the north where outcrops continue eastward to the Pennsylvania line. Rocks deposited in the latter half of the Mississippian time are not found in Ohio and therefore we can only suppose that the state was dry land in Late Mississippian times.

At the beginning of the Mississippian Period black shales continued to build in northern Ohio. Gradually the black mud gave way to silts and fine sands which sometimes became coarser and graded into gravels which have consloidated into conglomerates. In central and southern Ohio, sand and silt were accumulating instead of black shales. This was followed by periods of clear seas during which limestones were deposited.

In th lower Mississippian Waverly Group we find the oldest large body of sandtone and shales outcropping in Ohio. The lower part of the Waverly consist of shales, that are in some places hard to distinguish from Devonian shales. Silt and sandstone layers as we go upward in the column until they make up most of the rocks of the Upper Waverly formations.

The siltstones, sandstones, limestones and shales of the Waverly Group formations all contain fossils, but trying to find top grade fossils specimens is strictly a hit or miss proposition, for the preservation varies from faint impressions in shale or siltstones, or hollow molds in sandstone, to well preserved fossils of many varieties in the Logan formation. A lot of people overlook the heavy, hard ironstone concretions that are frequently found in the shale or siltstone formations; although I have found a few Conularid jellyfish in the gray shales, 95% have been enclosed in the hard concretions.

Up to four Conularid jellyfish have been found in one of the ironstone concretions, and I have even found both the Conularia micronema, and the Conularia newberryi in the same concretion. There are a variety of other fossils including brachiopods, pelecypods, crinoids, trilobites, gastropods and one lonely little blastoid, that has been found enclosed in these concretions.

Dr. Ausich of the Geology Department at Ohio State University is now studying that blastoid, and stated that from all of the literature he can find, it is the only blastoid that has been found in the Meadville Formation. Also in that concretion was a beautiful Schuchertella brachiopod, along with another small unusual looking brachiopod that Dr. Merrill Foster of Bradley University in Illinois, has been studying to try to find it's identification for me, so don't overlook these hard to open concretions that may conceal some rare treasures of ancient history. Remember!! - Opportunity knocks but you have to open the door, if you want to learn, or only by opening these heavy concretions will visions of former life be revealed to you. One of my greatest joys as a fossil picker was when I cracked open a concretion from the Cuyahoga Formation, and as I separated the two halves, the suns rays revealed the delicate pattern of my first and largest Conularia newberryi Jellyfish, which is now on display in a case of the Fryxell Museum, at Augustana College in Rock Island, Illinois.

INVERTEBRATE WAVERLY GROUP SPECIES IN OHIO

Fenestella delicata, Meek - Lower Carboniferous, Lodi, Ohio

Fenestella multiporata, Meek- var. Lodiensis," " "

Lingula membranacea, Winchell- Harts Grove, Ashtabula County, Ohio

Lingula melie, Hall - Cuyahoga Shale, Johnstown, Trumbull County, Ohio

Lingula scotica, Davidson - Berea Grit, Berea, Ohio

Discina newberryi, Hall - Cuyahoga Shale, Cuyahoga Falls and Akron, Ohio

Discina pleurites, Meek - Lower Carboniferous, Newark, Ohio

Hemipronites crenistria, Phillips -Lower Carboniferous, Medina County, Ohio

Productus (sp) - Lower Carboniferous, Sciotoville, Ohio

Athyris lamellosa, Leveille - Lower Carboniferous Sciotoville, Ohio

Spirifer carteri, Hall - Lower Carboniferous, Sciotoville, Ohio, and many others.

Spirifer biplicatus, Hall - Upper Waverly member, Richfield, Ohio

Entolium shumardianum, Winchell - Cuyahoga Shale, Richmond and Lodi, Ohio

Aviculopecten crenistriatus, Meek - Lower Carboniferous, Sciotoville, Ohio

Aviculopecten winchelli, Meek - Lower Carboniferous, Newark, Ohio

Schizodus medinaensis, Meek - Lower Carboniferous, Medina, Ohio

Palaeoneilo bedfordensis, Meek - Bedford Shale, Bedford, Ohio

Grammysia hannibalensis, Shumard - Waverly Sandstone, Medina, Ohio

Grammysia rhomboides, Meek - Waverly Sandstone, Medina, Ohio

Grammysia ventricosa, Meek - Waverly Sandstone, Medina, Ohio

Edmondia tapesiformis, Meek - Lower Carboniferous, Richfield, Ohio

Cardiomorpha subglobosa, Meek - Lower Carboniferous, Rushville, Ohio

Prothyris meeki, Winchell- Lower Carboniferous, Rushville, Ohio

Sanguinolites obliquus, Meek - Lower Carboniferous, Rushville and Newark, Ohio

Sanguinolites aeolus, Hall - Cuyahoga Shale, Medina County, Ohio

Promacrus andrewsi, Meek - Lower Carboniferous, Sciotoville, Ohio

Allorisma pleuropistha, Meek - Lower Carboniferous, Rushville, Ohio

Allorisma winchelli, Meek - Lower Carboniferous, Rushville and Newark, Ohio

Allorisma ventricosa, Meek - Lower Carboniferous, Rushville, Ohio

Platyceras lodiense, Meek - Lower Carboniferous, Lodi, Ohio

Waverly Species (Cont.)

Pleurotomaria textiligera, Meek - Lower Carboniferous, Medina, Ohio

Conularia newberryi, Hall - Cuyahoga Shale, Loudonville, Ohio

Conularia micronema, Meek - Cuyahoga Shale, Loudonville, Ohio

Phillipsia lodiensis, Meek - Cuyahoga Shale, Lodi and Loudonville, Ohio

REFERENCES:

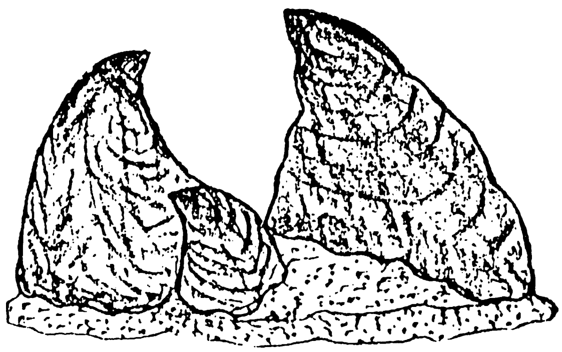
Geological Survey of Ohio, vol. II, Geology and Palaeontology Part II - Palaeontology, 1875

Bulletin 54, Ohio Fossils, by Aurele La Rocque and Mildred Fisher Marple, division of Geological Survey, Fourth Printing, 1961, Columbus, Ohio

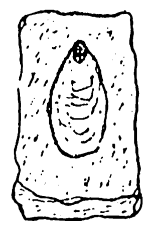
Illustrations:

Drawn by Author from fossils that he has collected from the Waverly Group Formation in the north central portion of Ohio.

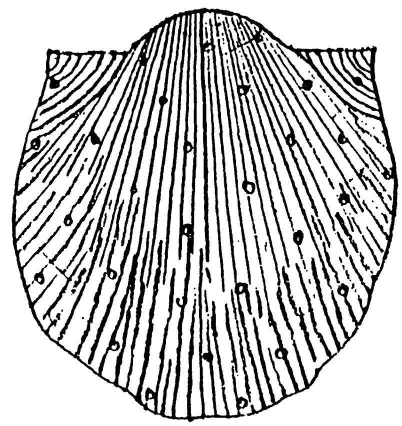
1 Location is hilly country in the southern part of Ashland County where a small stream winds along the bases of these hills of the Cuyahoga Formation, which at this location is composed of layers of light gray shales and siltstone to a height of 40 to 60 feet, topped by layers of sandstone that average 10 to 20 feet in height. When the thunderstorms bring high rushing waters along the bases of these hills, the errosive action of the water cuts into the layers of shale & siltstone, exposing ironstone concretions that are scattered through the layers of this formation. The fossils are usually of poor condition in the shales and siltstones, but about 1 out of 15 of the concretions when carefully cracked open may have a beautiful Conularid jellyfish, or a variety of brachiopods, pelecypods, or gastropods inside. One concretion that I opened in April of 1990 revealed 23 Platyceras lodiense snails!! Quite a bonus, for it is pure luck if anything over 2 in a concretion is found.



Platyceras lodiense

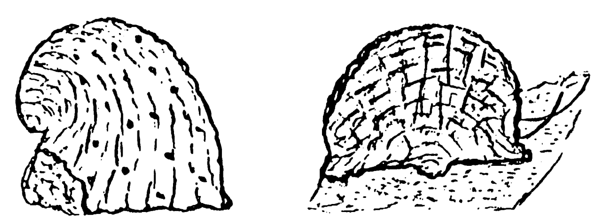


Lingula melie

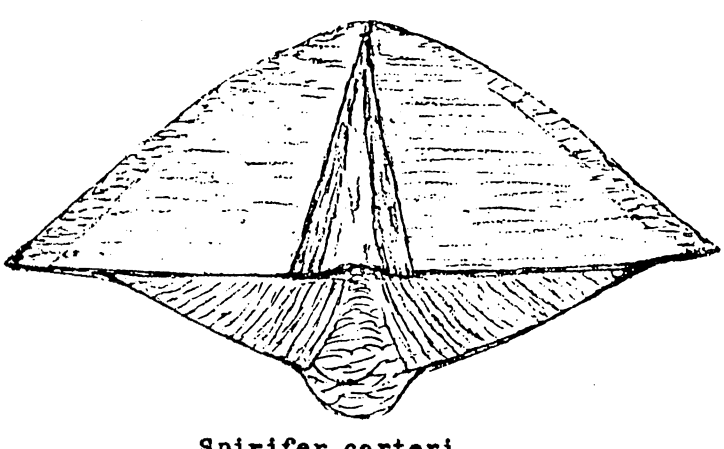


Buxtonia scabricula

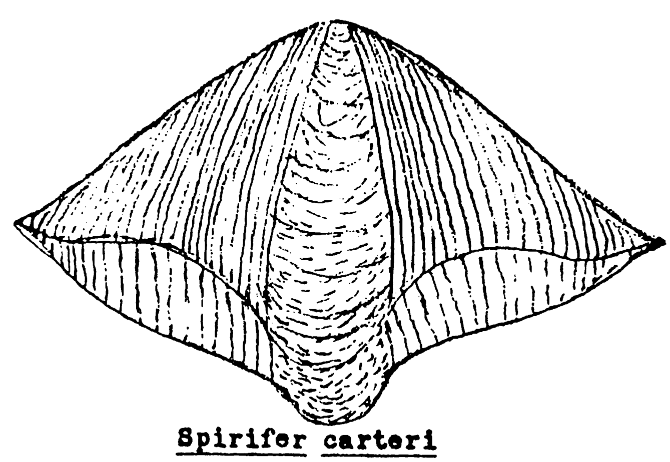
Conocardium cuneus



Productus



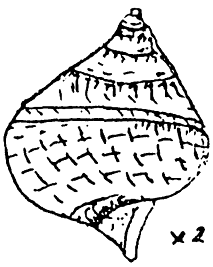
Spirifer carteri



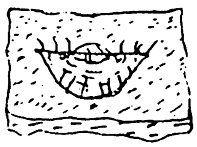
Spirifer carteri

2 Location is where a small stream has cut through the Meadville Formation in Medina, County near Homerville, Ohio. This Formation at this location is made up of layers of silty limestones, along with layers of gray shales. Scattered through the layers of shale and silty limestones are many ironstones concretions, from several inches to a foot in length. These are very hard and heavy. If you are lucky, about one out of thirty of these concretions when carefully cracked open, will reveal one or more well preserved fossils.

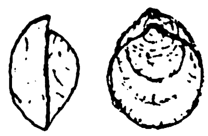
Two varieties of Conularid jellyfish, over fifteen varieties of brachiopods, three varieties of gastropods, two different genus of crinoids, one horn coral, one cephalopod, three varieties of pelecypods, one lonely blastoid, and a couple of bryozoa have been found at this location.



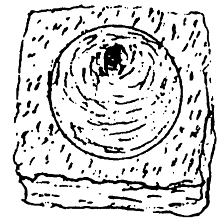
Mourlonia stellaeformis



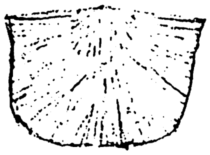
Chonetes glenparkensis



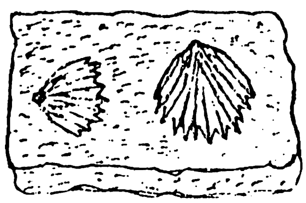
Girtyella flora



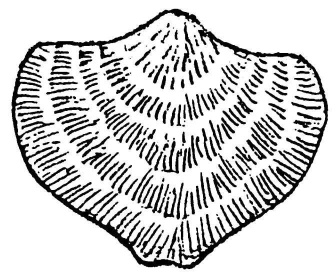
Orbiculoidea newberryi



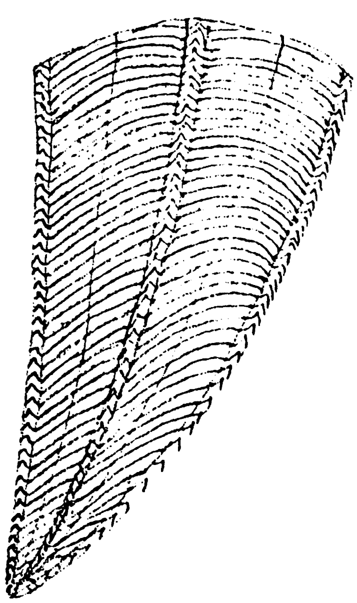
Schuchertella



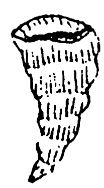
Ptychospira magna



Athyris lamellosa

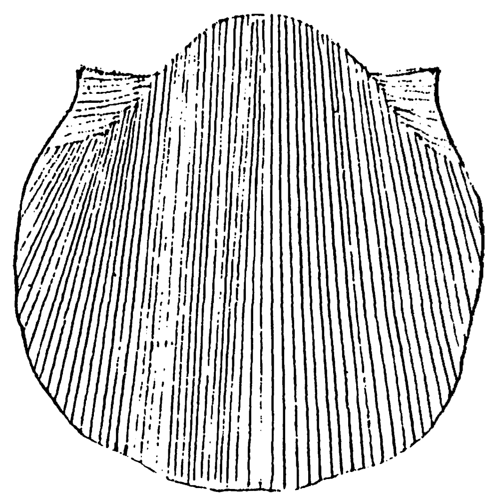


Conularia newberryi



Zaphrentis

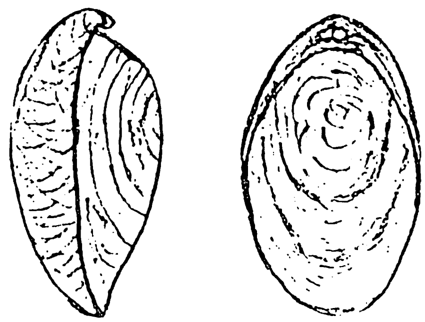
Marginifera



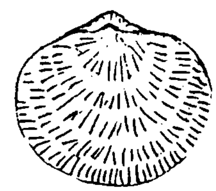
Dictyoclostus

3 Location is where a small stream along the base of a tree covered hill has exposed layers of dark gray shale and siltstone of the Logan Formation in the northern part of Ashland County. The fossils here are found mostly in the dark gray shales, with a few found in the ironstone concretions. The exposure is about a 30 foot high bank that tapers to about one foot in a length of approximately 100 feet.

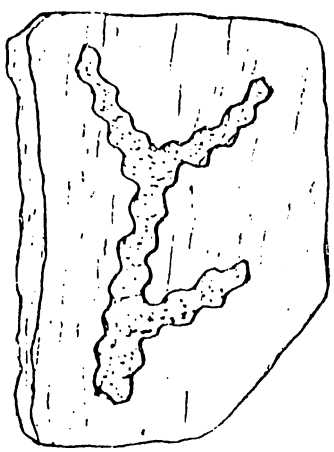
Here quite a variety of fossils are found, including brachiopods, pelecypods, cephalopods, a few small bump covered trilobites, gastropods, crinoids - one which turned out to be a "one of a kind specimen" with a small complete crinoid crown lying across a large complete crinoid crown, and one small blastoid. the "One of a kind crinoid Specimen" is in a display case at Fryxell Museum in Augustana College at Rock Island, Illinois



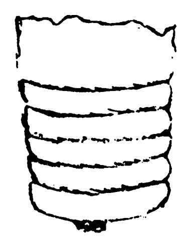
Girtyella sp.



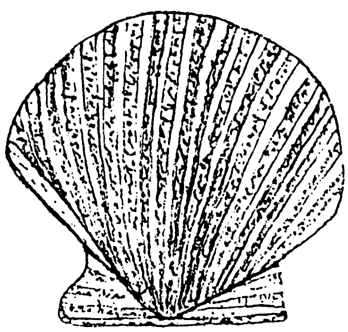
Rhipidomella



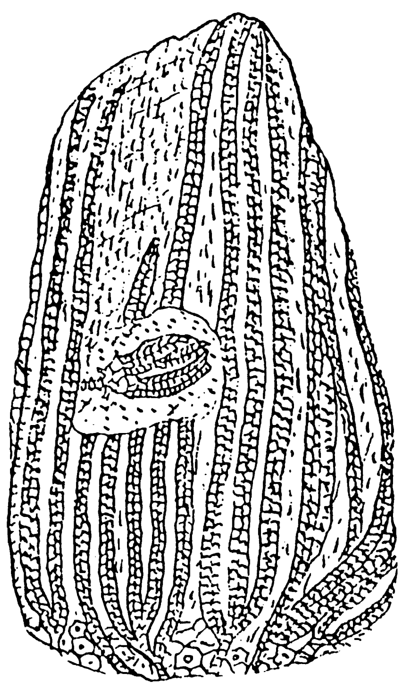
Ptilodictya serrata



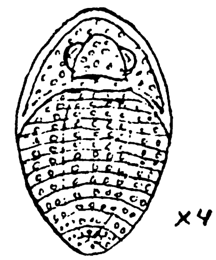
Michelinoceras



Aviculopecten winchelli



Paracometocrinus richfieldensis on Cusacrinus daphne



Brachymetopus rusticus

THE HARAGAN FORMATION OF OKLAHOMA - A LOWER DEVONIAN TREASURE TROVE OF INVERTEBRATE FOSSILS

Mark G. McKinzie
8702 Acre View Rd.
Oklahoma City, OK 73151

INTRODUCTION

The Haragan formation of Oklahoma has long been known as a rich horizon for collecting lower Devonian fossils, and trilobites in particular. Since the turn of the century. the "White Mound" collecting area in the Arbuckle Mountains of Murray county has been a favorite field trip spot for the Geology Department from the University of Oklahoma. Specimens from there have found their way to museums and collections all around the world. Renewed interest in the Haragan trilobites has been spurred on by the leasing of an even more prolific section at Old Hunton Townsite in Coal county, Oklahoma.

The leasees of the quarry are after apparent zones rich in what were once rare trilobites such as Leonaspis williamsi, and Dicranurus hamatus elegantus among others. In the process of removing the overburden to reach these thin, rich horizons, the leasees have exposed a nearly complete section of the Haragan up to the overlying Bois d'Arc contact. The Bois d'Arc formation is also lower Devonian in age and a member of the Hunton Group. This paper deals with observations I have made concerning the fossil distributions and the environment of deposition at both the Old Hunton Townsite, and the White Mound collecting localities.

AGE AND CORRELATION OF THE HARAGAN FORMATION

The Haragan formation is a member of the Hunton Group which is a series of carbonate shelf deposits ranging in age from very late Ordovician to late-middle Devonian. In Oklahoma, the Haragan rests unconformably on the upper Silurian Henryhouse formation, and is in turn overlain by the Bois d'Arc formation in the Arbuckle Mountains region. Many consider the Bois d'Arc to represent a shallow-water facies of the Haragan formation. Lithologically, the Henryhouse formation looks exactly like the Haragan formation in most outcrops though it is usually not as marly. Based on trilobites, Brachiopods, and ostracods, the Haragan formation is considered equivalent to the New Scotland-Lalkberg formations of New York abd adjacent areas. They are both of the Helderbergian stage of the Ulsterian series (lower Devonian).

There is also a similairity between the Haragan faunas and the Birdsong-Ross of Tennessee.

ZONATION OF FOSSILS AT OLD HUNTON TOWNSITE

The marlstones and shales of the Haragan formation at Old Hunton Townsite contain numerous zones or layers rich in a particular fossil or group of fossils. The most famous of these zones is an approximately one foot thick layer rich in the articulated remains of the spinose trilobite Leonaspis. This does not mean that Leonaspis is found only in this one foot interval, only that it is much more common here than above or below it. Other trilobite rich zones have been identified above and below this layer but have not been as extensively worked.

Zones rich in other fossil groups have not been established but this is probably due to the fact that the emphasis on collecting has been placed on the trilobites. In addition, bulldozing of the overburden has revealed bedding planes rich in fossils.

Between these rich layers are alternating "barren" zones. These layers are not totally devoid of fossils but have low diversity/low frequency faunas compared to the rich horizons. What do these recognizably rich zones mean, and what do they relate to the environmental conditions at the time of deposition?

I personally believe that there are numerous small-scale disconformities within the Haragan formation which represent periods of non-deposition (rather than erosion) when the lime mud machine was temporarily turned off. The problem with identifying disconformities within a massive limestone or marlstone unit such as the Haragan formation is that there are not always any tell-tale markers left in the sequence. You do not have an abrupt lithology change from limestone to sandstone or shale for example. Then you have to concentrate on changes in the faunal composition thru time. The problem encountered here is when the timespan is one of relative shelf stability, and the rate of evolution is slow and there are no drastic changes in faunas for millions of years.

Possible causes of disconformities include sea-level fluctuations that change the environmental factors that control carbonate precipitation. Changes in the sediment supply reaching a coastline also affect the matrix composition offshore. A muddy seafloor that suddenly received a dramatic increase in sand and content would over time change from a marlstone to a sandy limestone or limey sandstone.

In turn, the bottom-dwelling community would change from one that preferred turbid waters to one adapted to clear waters.

A concept that has been applied sucessfully to fossil zonations within carbonates of the Helderbergian series of New York) and especially the Middle Devonian Hamilton Group) is that of PACS. PACS stands for Punctuated Aggradational Cycles (see Figure 1). Trilobite rich zones, such as the Leonaspis zone represent smothered-bottom assemblages. They indicate rapid burial of extensive areas of the sea floor by storm-generated mud clouds moving gravitationally downslope. These zones mark the punctuation event indicated in Figure 1. As such, these tempestites (marine storm deposits) are of single event orgin and represent an actual freeze frame of the storm deposits were probably deposited in a time span of a few hours to a day maximum.

The barren zones, on the other hand, represent periods of normal marine conditions for the area with the usual rates of accumlation of sediment and organic debris on the sea floor. As I stated before, this does not mean that there are not any fossils in these intervals, only that their relative abundance is much less than the rich zones. In realtime, these zones account for the days to weeks to months between episodic punctuation events (storm deposition). This pattern was repeated time and time again during deposition of the Haragan formation. Evidence for the occurance of (PACS:1) enrolled trilobites. A reaction to environmental stress, caused by a sudden change in the surrounding environment. In this case the change was caused by the dense mud layer sweeping downslope and enveloping everything in its path. Enough mud was dumped on the trilobites to essentially suffocate them. The dalmanitids (Huntonia), phacopids (Paciphacops, Reedops), and the Odontopluerids (Leonaspis) are all commonly found in semi-enrolled to enrolled positions.
(2) excellent preservation of fossils - little or no compaction/distortion, and no disarticulation (most disarticulated phacopids are probably moults). There is also little evidence of prolonged exposure at the sediment/water interface for any period of time after death (encrusting epibonts or etched exoskeletons). This is especially true of the delicate spinose forms such as Leonaspis, Discranurus, and Ceratonurus.

(3) Random orientation of adjacent fossils (inculding trilobites) lying at oblique angles to one another. If there were any strong currents at the time of deposition then there would be a preferred orientation of at least some of the fossils. I have seen numerous blocks of trilobites touching each other with one lying "face-up" and the next one lying "face-down".

An important point to keep in mind about zones like these is that they represent a true portrait of the bottom-dwelling community at the time of burial. These invertebrates died in place with little or no transportation, and show the relative distribution of life on the sea floor along that horizon.

The other type of layer rich in fossils is the bedding plane surface literally covered with fossils. This is caused by another type of depostional process entirely. In this case it represents a temporary hard ground in which the carbonate mud machine slowed down or was turned off long enough for a series of benthos to live and die at the spot over time. The creatures living on the sea floor were not immeadiately buried in the muck but were exposed at the surface for some time. This led to skeletal disarticulation, and destruction of the exoskeletons by both organic and inorganic factors.

Organic elements included scavenging by other invertebrates which promoted decay of the carapaces, and incrusting by epibonts such as the auloporid corals which further weaken the skeletons. Non-organic forces included the rolling and tumbling of fossil debris along the sea floor by gentle currents that scoured the sea bottom at times.

FOSSILS AS ENVIRONMENTAL INDICATORS

I have compiled a listing of fossils collected from both Old Hunton Townsite, and White Mound (see Table 1). the trilobites, brachiopods, ostracods, and crinoids have been covered in detail by various authors. Published descriptions of these fossil groups can be found in various Oklahoma Geological Survey bulletins and circulars.

Fossil groups that have been negelected in the past include the corals, sponges, bryozoans, and the various mollusk classes. The preservation of the mollusks is generally very poor. Usually only an internal, external, or composite mold is preserved. This is due to the inherit instability of the aragonite shells to survive burial and diagenesis in most marine environments. The other shelly faunas yield numerous and complete specimens.

Life forms are not preserved in the fossil record at these two localities include such soft-bodied organisms as:

(1) jellyfish
(2) non-calareous algae
(3) seaweed/ aquatic plants
(4) sea slugs
(5) polycheate worms
(6) crustaceans with apatite-phosphatic carapaces

I find it hard to believe that these forms were not present in the early Devonian seas. The remarkable fossils still being described from the Burgess shale outcrops proves that all the above mentioned groups were established by the time of the Cambrian explosion. Even at rich outcrops like these two where you can literally view a thousand fossils in a given day. I walked away feeling that I have not glimpsed half the life that was swimming, crawling. and burrowing at the time.

The following is a listing of fossils from the Middle Devonian of New york, and how they have been used to infer bottom conditions at the time of deposition. Most of the inferences can also be successfully applied to the Haragan formation:

FOSSIL	INFERENCE
Complete phacopid trilobites with cephalon at oblique angle to thoracopygiduim	inferred semi -infaunal life position
Separated cephalons & thoraco-pygidiums	molts
Encrustation of epibonts (bryozoans, auloporids, pluerodictyum)	long term exposure at sediment-H2O interface
Coral Pluerodictyum	sediment-tolerent species withstand murky bottom
Large-eyed phacopid trilobites	within photic zone
Herbivorous gastropods (Pleurozygopluera & Retispira	presence of algae and seaweed on bottom
Brachiopods with wide interareas (Mediospirifer), alate wings (Mucrospirifer), Strongly concavo-convex shells (strophomenids)	forms adapted to life in a soft substrate such as a limey mud: unstable

Nuculoid bivalves	inhabit muddy substrates:burrow 2-3 cm down & vigourously rework sediment
Spinose trilobites (Leonaspis)	adaptive trait that allow it to settle on a shifting substrate (mud
Beds of enrolled trilobites	death assemblage caused by behavioral response to environmental stress
Long cylindrical, & robust	closely resembles dwelling tubes of living polycheate (Clymenella)
Fragmented/ disarticulated remains	presistent current agitation: exposure on surface for extended periods of time

All these are present to some extent at both Old Hunton Townsite and White Mound. During the early Devonian, a continuous and open seaway existed from Brunswick, Canada southwest into Northern Mexico well past El Paso, Texas. Paleomagnetic studies indicate that this shelf lies approximately 10 to 15 degrees south latitude of the equator along its entire length. Being this close to the equator, the average mean temperture would only vary slightly throughout the year as winters would have been nearly non-existant.

The trilobites of the Haragan formation are very similiar to the trilobites from the New Scotland - Kalkberg of New York. In fact, it is suprizing how similiar the faunas are considering the physical distance between the two areas. The Haragan, and the shallow-water Bois d'Arc trilobites may be regarded as a filtered Appalachian assemblage with regional differences caused by evolution occuring thru time as the faunas migrated along the coastline from east to west. However, some barrier did exist that filtered the migration of some families of trilobites while allowing others to move freely up and down the coast. This same pattern of filtering has been observed in the other major fossil groups that have been studied in detail.

The main reason for its wide-ranging distribution is the presents of a bulbous float during some stage of its adult life. This chambered bulb allowed it to be carried with the currents to all the oceans at the time. Of course its survival anywhere depended upon favorable living conditions wherever it drifted to. South of Ada in the Lawrence uplift, there are layers in the Bois d'Arc containing hundreds of the bulbous roots. Rarely are crowns and bulbs found together. The Bois d'Arc is a higher energy faces than the Hargan formation to the south, and apparently it was common for the bulb to be ripped from the stems and to drift shoreward while the stem and crown settled to the bottom. Or perhaps at some time in its adult stage the Sycphocrinites willingly separated from its bulb to colonize on the bottom. Wave action concentrated the bulbs in swash zones near shore where we find them today in the Bois d'Arc.

THE SEA FLOOR DURING DEPOSITION OF THE HARAGAN FM.

In today's tropical waters, the lower limit of the PHOTIC ZONE is 100 meters (300 feet). Above this, enough sunlight filters thru the seawater for light-seeking plankton to survive and reproduce. Below this total darkness. Of course plankton are at the bottom of the food chain, and where they live there are bound to be predators around to feed on them. This is where the majority of organic activity takes place on today's ocean floor and by analogy the same holds true for Paleozoic sea bottoms. this is the inferred maximum limit of deposition of the Haragan formation at Old Hunton Townsite, and White Mound. The shear numbers and diversity of fossils at these two localities indicate that the sea floor must have been within the PHOTIC ZONE.

A significant portion of the fossils present also indicate a muddy substrate and not a sandy or rocky bottom. the rock matrix has a high level of HCL insolubles which indicates an original high mud content. The lack of bedding indicates quite-water conditions with a uniform sediment supply. This would be expected far from shore, and below normal wave action. The lower limit of storm wave base along modern tropical shelves is 40 meters (120 feet). This then is the upper limit for deposition of the Haragan formation at these two localities (see Figure 2). The ocean bottom during deposition of the Haragan was between 120 and 300 feet below sea level.

During periods of normal deposition, the bottom was a very gentle sloping shelf (essentially flat) under quite-water conditions. The setting was miles from the ancient shoreline. The seafloor overall was very muddy, but in places has a patchy hardground caused by an increase in sand content or some type of early cementation of the mud. The seawater was well oxygenated and nutrient-rich.

The conditions were favorable for an abundance of life on the sea floor. The benthos were dominated by forms adapted to life on a muddy bottom that could tolerate slightly turbid water conditions. These forms include the strophomenid and spirifed brachiopods, the coral Pluerodicyum, and spinose trilobites such as Leonaspis.

Occasionally large storms/hurricanes slammed into the coastline. The storm-generated waves did not affect the sea bottom directly this far off shore. However, large clouds of mud were churned up at shallower depths near shore. Some of this would be swept out to sea as the storm energy diminished.

The mud clouds would travel gravitationally downslope, into deeper water as a dense layer riding underneath the sea water above it. As the mud clouds moved downslope, the velocity would diminish and the sediment (mud) would settle out onto the sea bottom. All the creatures on the sea floor would rapidly become buried in a thick layer of mud that could be several inches thick. Those invertebrates (especially the sessile ones) that could not quickly burrow out of the mud would quickly become entombed in the muck and die. Most of the trilobites would instinctively enroll into a protective position then the mud could hit. this is how the smothered bottom assemblages are preserved in the rock record, and may explain some of the rich trilobite layers at Old Hunton Townsite.

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3) Brett, Carlton E.; Speyer, Stephen E.; 1986. Trilobite Taphonomy and Middle Devonian Tapofacies - Palois, vol. 1, #3, p.321-316.

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5) Strimple, Harold L.; 1963. Crinoids of the Hunton Group, Oklahoma Geological Survey, bulletin #100 p.7,8,15.21.

FIGURE 1

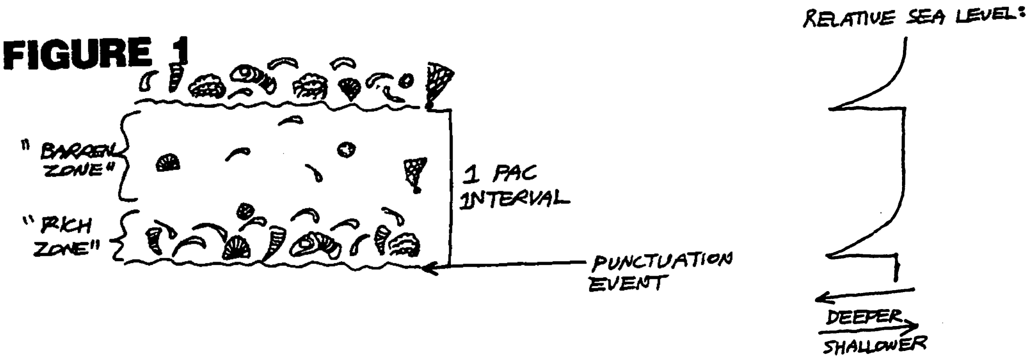

FIGURE 2

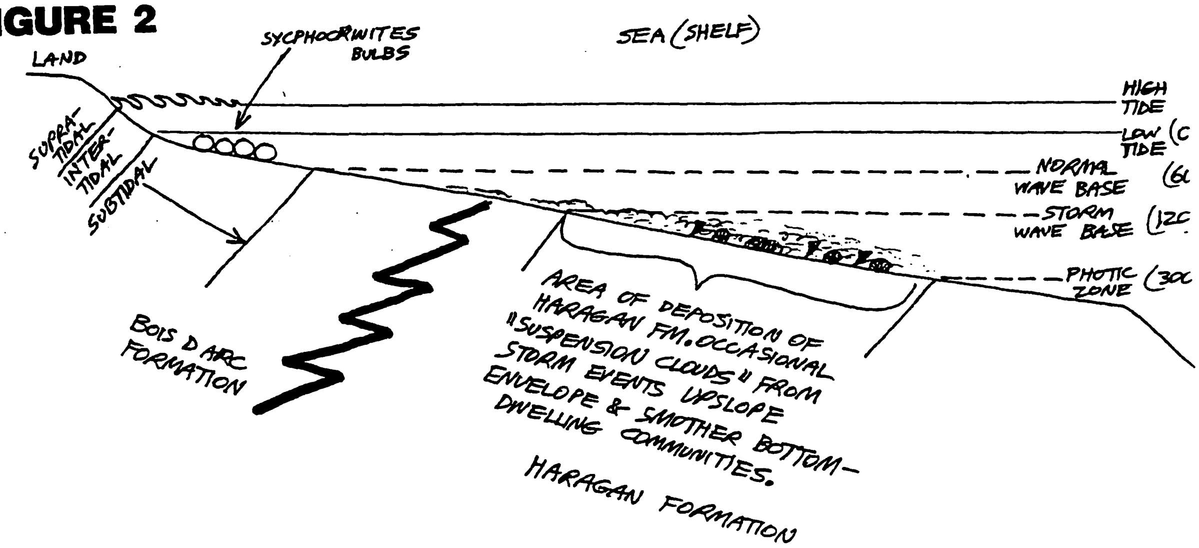

TABLE 1

HARAGAN FM. FAUNAL LIST:
(LOWER DEVONIAN/HELDERBERGIAN AGE)
MURRAY & COAL COUNTIES, OKLAHOMA

Taxa	MODE OF FEEDING
TRILOBITES (11)	
Dicranurus hamatus elegantus	EPIFAUNAL - MOBILE COLLECTORS (SOME POSSIBLE INFAUNAL DEPOSIT FEEDERS)
Leonaspis williamsi	
Ceratonurus sp.	
Huntonia oklahomae, H. purduei,	
Huntonia lingulifer	
Cordania falcata	
Otarion exitosum	
Paciphacops raymondi	
Reedops deckeri	
Echinolichas coccymelum	
CEPHALOPODS (1)	
Kionoceras sp.	NEKTONIC CARNIVORE
GASTROPODS (5)	
Platyceras cornatum	EPIFAUNAL -MOBILE COLLECTORS
Platyceras unguiforme	
Mourlonia sp. — INTERNAL MOLDS ONLY	
Anomphalus sp. — INTERNAL MOLDS ONLY	
Bembexia sp. — INTERNAL MOLDS ONLY	
PELECYPODS (3)	
Grammysia arcuata	INFAUNAL FILTER-FEEDERS
Actinoptera textilis	
Orthonota sp.	

Taxa	MODE OF FEEDING
CRINOIDS (3)	
Edriocrinus dispansus	ELEVATED-SUSPENSION FEEDERS "FLOATING" NEKTONIC
Mylodactylus nodosarius	
Scyphocrinites gilbousus	
TABULATE CORALS (4)	
Pluerodictum lenticulare	SESSILE MICRO-CARNIVORES
Emmonsia emmonsi	
Aulopora elleri? — EN-CRUSTING	
Cladopora sp. — EN-CRUSTING	
RUGOSE CORAL (1)	
Enterolasma strictum	SESSILE MICRO-CARNIVORE
SPONGES (3)	
Hindia fibrosa	EPIFAUNAL FILTER-FEEDERS
Shaerospongia sp.	
unidentified siliceous sponge spicules	
BRACHIOPODS, ARTICULATE (24)	
Anastrophia grossa	EPIFAUNAL FILTER-FEEDERS
Atrypa oklahomensis	
Atrypina hami	
Camartoechia biralvata	
Bilobites varicus	
Cyrtina sp.	

Taxa	MODE OF FEEDING
ARTICULATE BRACHS (CONTINUED)	
Isorthis pygmaea	EPIFAUNAL FILTER-FEEDERS
Kozlowskiella velata	
Leptanea acuticuspidata	
Leveana pumilis	
Meristella atoka	
Meristella choctawensis	
Orthospira strophomeinoides	
Platyorthis angusta	
Rensselaria haragana	
Rhipomelloides oblata	
Rhyncospirina maxwelli	
Rhyncospirina formosa	
Sphaerynchia glomerosa	
Sphaerynchia lindenensis	
Strophonella bransoni	
Stropheodonta arata	
Stropheodonta gibbera	
Uncinulus sp.	
BRYOZOANS (5)	
Batastomella granulifera	EPIFAUNAL FILTER-FEEDERS
Fenestrellina stellata	
Petalotrypa compressa?	
Reptaria stolonifera?	
Sulcoretepora incisurata	

RIVERSLEIGH
SPLENDOURS OF AUSTRALIA'S PAST

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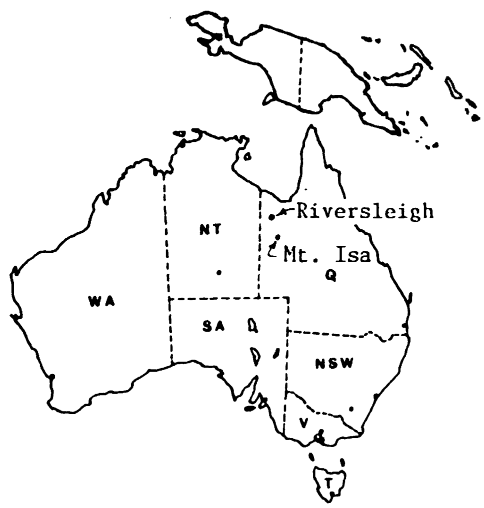
The Gulf country of northwest Queensland is mostly a dry, unfriendly place. Low spinifex covered mesas look out over parched scrubby plains. Trees are few and permanent water is rare. But where there is water, in the O'Shaunassy and Gregory rivers, there is abundant and diverse life. These sinuous ribbons of blue and green stretch for hundreds of kilometres across the ochre and red of the savanna. This is a timeless place, as if it were incontrovertible proof that Australia had always been the dry continent. It seems ironic that from this inhospitable corner of Australia comes startling fossil evidence that this area was once covered by lush, tropical rainforest.



Riversleigh Station near the Queensland-Northern Territory border, is now recognised as the pre-eminent vertebrate fossil locality in Australia and one of the best in the world. The quality of the fossils and the diversity of animals that they represent is unprecedented in Australia. Another unique feature of the Riversleigh locality is the time span represented. Most of the Middle to Late Tertiary is represented from the oldest sites, some 25 million years old, to Recent stream deposits that are probably less than a few tens of thousands years old. From this rich fossil record we are learning a great deal about an unknown Australia, a lost continent that few Australians would recognise.

Riversleigh has concealed its treasures from palaeontologists by its isolation and inhospitable environment. The stories of the first fossil discovery at Riversleigh are anecdotal. A Cobb & Co., coach road passed the edge of the deposits on its way from Mt.Isa north to mining fields at Lawn Hill. Supposedly, around the turn of the century, a passing coach broke down in front of some rocky bluffs and, while waiting for repairs, one of the passengers stumbled upon some fossil bones. Other stories claim that mining prospectors found the first bones at Riversleigh. Either way some fossil bones from Riversleigh were sent to the Queensland Museum where they remained largely unnoticed until the 1960's.

In the mid 1960's Dr. Dick Tedford, a visiting American palaeontologist, refound the specimens in the museum. Tedford realised that this material represented a type of preservation not previously seen in Australia and guessed that the animals they represented were probably older than those known from other Australian deposits. This was enough for him to organise a small expedition to the locality where he confirmed his ideas about the nature of the deposit. However, Tedford thought that the deposit was a very restricted one, representing the edge of a lake deposit that had mostly eroded away. Further, the limestone was difficult to handle and even more difficult to process. Around the same time Tedford also explored deposits in Central Australia that were easier to work, more extensive and more productive. With such temptations elsewhere, Tedford concluded that, although interesting, the Riversleigh deposit did not warrant further expeditions.

The Riversleigh fossil deposit was virtually left alone for almost a decade until Dr.Mike Archer, then the Curator of Mammals in the Queensland Museum, revisited the site in the late 1970's. Dr. Archer (now Professor of Biological Science at U.N.S.W.) was intrigued by the Riversleigh fossils and began a systematic collection of them. He found that the fossils were easy to prepare using dilute acetic acid. Those released from the rocks were even more provocative than first thought; large crocodiles and huge birds, early diprotodontids and numerous turtles. Most of these animals were new species, even new genera, but all were relatively large, robust creatures, and similar or identical animals could be collected from the Central Australian localities. The puzzle of Riversleigh was the lack of small animals and the deposit still seemed to be quite restricted in size.

Archer returned to Riversleigh each year from 1976 onward, but the first real indications of its potential occurred in 1978 when Henk Godthelp, Mike Archer's assistant, began exploring over the top of the hill. To his surprise, he found a limestone block encrusted with thousands of bat fossils. For the first time Riversleigh had produced small animals and more importantly animals that were not known from anywhere else. When prepared in acid, blocks of limestone produced perfectly preserved bat skulls as small as a thumb nail - they fell out of the rocks by the hundred.

By 1983, working Riversleigh was becoming a bit of a chore; the fossils collected were generally the same as those already found or of animals more easily collected in Central Australia. Only the bat fossils and their associated faunas made Riversleigh a more attractive locality than Central Australia. However, 1983 was a red-letter year in the history of exploration of the Riversleigh deposits. Ken Grimes, of the Queensland Geological Survey, and Mike Plane, of the Bureau of Mineral Resources, were studying coloured aerial photographs of the Riversleigh area, when they noticed that the fossil-bearing rocks were distinctively paler than the older Cambrian Limestones and extended deep into the plateaus to the west. A smaller plateau west of the known deposits was earmarked for exploration during the expedition later that year. This latter plateau is now known as Gag Plateau as that was all the expedition could do when they saw the stunning variety and density of specimens contained in its rocks. In areas the rocks were crammed with fossils of kangaroos, koalas, marsupial dogs, marsupial lions, various new diprotodontids, platypuses, turtles, crocodiles, lungfish, birds, bats, even animals that represent new marsupial orders. Most were new to science, in the order of 15-20 million years old, and all exquisitely preserved.
Since 1983, other areas have been explored and found to contain similar assemblages of animals but of slightly differing ages, mostly within the Late Oligocene to Middle Miocene.

Riversleigh field trips had become a yearly event with teams of volunteers going to northwestern Queensland to assist the ever growing band of scientific staff headed by Dr. Archer. Teams of up to 40 people would camp on the banks of the Gregory River for up to a month during the dry season. The Gregory River was a popular holiday destination for residents of Mt. Isa and it was only a matter of time before some of these people also joined in the Riversleigh fossil hunt. Two such locals are Alan Rackham and his son, Alan Jnr. Alan Snr., is a ring blaster in the mines at Mt. Isa and his knowledge of explosives has proved invaluable in the quarrying of some sites. Alan Jnr., has also helped the Riversleigh saga in many ways, not least of which were the discoveries he and his father made during 1985.

While walking in an entirely different area to the known fossil sites, the Rackhams noticed large ribbons of a pinky coloured stone that Dr.Archer had asked them to keep an eye out for. The pink stone was known to be fissure fill material but, until that time, none had been found to contain any fossils. The area that the Rackhams had found (now known as Rackham's Roost) was extensive and fossil rich. A few tonnes of this material was collected that year and processed to reveal numerous bats. These bats were significant for two reasons; they were younger than the known deposits (about four million years old) and they were mostly small, badly fragmented remains. Ghost bats (carnivorous bats that feed on small mammals, lizards and frogs) originally roosted in the unfilled fissure and would go out foraging at night returning to the roost with their prey. After the meal, the bones of their prey would fall to the floor of the fissure thus compiling a faunal list of small animals of the foraging range of the Ghost Bats. The most interesting component of the Ghost Bat menu is the large range of rodents, the earliest record of this group in the Riversleigh area and one of the earliest records of rodents in Australia.

The Rackhams feature highly in the exploration of Riversleigh. The year before the discovery of Rackham's Roost, the Rackhams were exploring along the river banks to the east of the main fossil deposits. Here they found the youngest deposits so far discovered at Riversleigh; stream overbank deposits that are only a few tens of thousand years old. From these sites come remains of the largest marsupial ever, Diprotodon optatum, a large crocodile Pallimnarchus, the first fossil of the Australian Freshwater Crocodile, turtles and other assorted animals. In 1987 Dr. Sue Soloman, of New England University, excavated some ochre from these sites suggesting that humans may have been in the area but this is yet to be confirmed.

To date, the vertebrate fossil record of Riversleigh extends from the Late Oligocene (around 25 million years ago) to the Recent river deposits that are perhaps only 10 thousand years old. The deposits at Riversleigh rest on the edge of a huge Cambrian limestone shield from which trilobites and hyolithids have been recovered. Both the Tertiary and the Cambrian limestones rest on a Precambrian quartzite basement that has many stromatolite formations. In a few places in the Riversleigh area, all three ages of sediments are in close proximity to each other. One can stand on Precambrian stromatolites and look past Cambrian limestones to see the fossil-bearing Tertiary formations. It is rather magical to be able to view with such ease a condensed history of that part of Australia.

Another magical phenomenon that frequently occurs at Riversleigh is the unparalleled thrill of breaking open a rock to be the first to view a pristine specimen of an entirely new animal. But such magical moments have their costs. It is not an easy job to collect fossils there as the limestone is extremely hard. Explosives are used to gently crack huge blocks which can then be pried part with crow bars and reduced to manageable sized pieces with sledge hammers.

Pieces can be easily transported in hessian sacks but large blocks that are particularly rich in fossils are often taken in one piece. Drilling blast holes, lugging crowbars, swinging sledge hammers and carrying blocks of limestone up to half a tonne in weight is not easy work at the best of times. Such work is even more arduous in 35°C heat, in rough terrain, with millions of flies and only the water you have carried from camp that morning to cool you down. Moving large blocks and heavy bags over the ridges and down onto the plains is also no mean feat. The limestone weathers into murderous sharp peaks and spiky spinifex grows in profusion, one slip usually means a cut, a bruise and a heavy sample on top of you! Most vehicles cannot climb very far into the hills from the plains but an ex-Army four wheel drive truck generously donated by Dick Smith and Australian Geographic, can get into many places other vehicles cannot. Army helicopters have been used to move rocks and equipment over the roughest terrain and in the last few years, Wang Computers have generously donated money for cattle mustering helicopters to do that job. Each year the scientific team and the small army of volunteers that perform these backbreaking tasks usually manage to move around 25 tonnes of the fossil-rich limestone to a collecting point from which the Mt. Isa Shire Council ship it to the railhead at Mt. Isa.

Once in Sydney the limestone is placed in large vats of dilute acetic acid donated by I.C.I. Periodically the limestone and fossils are removed from the acid, washed and coated with strengthening agents, then returned to the acid. Getting the fossils out of the rock can be a long slow job or relatively quick depending on the composition of the limestone. Invariably the fossils that are produced by this process are more than worth the effort.

It will take many volumes to fully describe the finds of Riversleigh and their significance so I do not intend to go into great depth here. However, some of the more spectacular finds include: A complete skull of an ancestral platypus with a perfect natural brain cast; two new orders of marsupial; the skull of an early diprotodontid so beautifully preserved that unwary palaeontologists, seeing it for the first time, could be fooled into thinking it died yesterday; hundreds of bat skulls, some as small as a little finger nail; perfectly preserved skulls and jaws of early carnivorous kangaroos; skulls of early marsupial lions; ancestors of the recently extinct Tasmanian Tiger; teeth and limb bones of an ancestor to the marsupial Mole; primitive koalas; an astounding diversity of possums and cuscuses; giant crocodiles with teeth four times the size of their modern counterparts and other, smaller crocodiles that made a living on the land; giant snakes; birds ranging from tiny songbirds to huge emu-like creatures that stood ten foot-tall; a variety of turtles; lungfish and other fish; over twenty types of frog; and, most unusual in this chemical environment, some insect and arthropod shells.

Clearly, Riversleigh is a palaeontological treasure trove with no parallel in Australia and few comparable deposits anywhere in the world.

So what do all these beautiful fossils tell us about the history of Australia? It is quite clear that such a diversity of wildlife could not be supported at Riversleigh today. In fact the number of organisms and particularly the diversity of leaf eating creatures such as the possums and cuscuses, indicate that Riversleigh was a rich and varied rain forest during the OligoceneMiocene epochs. It is very hard to imagine Riversleigh as rain forest today, although the banks of the Gregory and O'Shaunassy Rivers do support a thick vine forest that is the severely depleted remnants of the original vegetation. A better picture of what Riversleigh might have been like is the mid-montane rain forests of the New Guinea Highlands. These forests were once continuous with the forest at Riversleigh but as the Australian Plate moved north and the Highlands rose they created a rain barrier that deprived Riversleigh of the rains from the north east. As the Riversleigh forests contracted and died, a small remnant of the New Guinea forests was pushed higher and higher to its present position.

As the forests around Riversleigh died, the animals had two destinies; die with the forests or adapt to the new, drier conditions. Today, Australia is populated by the descendants of the animals that could adapt to increasing aridity. Moles, grubbing through the leaf litter of the ancient forests, were preadapted to moving through the sands of the desert. Koalas and possums were adapted to the less nutritious eucalypt leaves that were left after the diversity of leaves in the ancient rain forests had vanished. Browsing animals such as the diprotodontids and sthenurine kangaroos were replaced by the grass-eating macropodid kangaroos. Larger carnivores such as the marsupial Lion and the Thylacine survived the drying of the continent only to be wiped out with the coming of man and the Dingo. The crocodiles of the ancient forests were replaced by an invader from Asia, the animal we now call the Salt Water Crocodile.

Many of the animals found at Riversleigh have no living descendants they are totally extinct. Others are locally extinct, their descendants being found elsewhere. Few of the animals represented by fossils found at Riversleigh have direct descendants still in the area today. This dramatic turn over of Australian fauna has happened relatively recently. In a very real sense, it is a testimony to the drastic results of a rain forest being replaced by a desert.

The research into the fossil deposits at Riversleigh has only just started and the mountain of material that is being uncovered should keep palaeontologists occupied for a few hundred years or more. It is essential that the sites are not interfered with. Our greatest enemies are ignorance and vandalism. Luckily, the sites are very hard to find and relatively inaccessible. They are also on private land and uninvited visitors are not welcome. Should you wish to visit the sites or if you wish to participate in field work at Riversleigh, contact Campbell's Tours, Mt.Isa. Information on the activities and discoveries of the Riversleigh Research Group is distributed by The Riversleigh Society. Further, The Riversleigh Society offers a unique opportunity to keep up to date with the most recent developments in Vertebrate Palaeontology throughout Australia through its publication, Riversleigh Notes. If you are interested in joining the Society, further details can be obtained from :-

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Written by Paul Willis, President of The Riversleigh Society, and reprinted by his permission.

THE BRANDON BRIDGE FAUNA

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In his marvelous book WONDERFUL LIFE, Stephen Jay Gould lists six Lagerstatten. One of these mother lode faunas preceded and four followed the subject of his book, which was the Burgess Shale Fauna, the granddaddy of them all. during a nine month period spanning from 1983-1984 we had the thrill of collecting fossils in one of these layers: a diverse array of soft-bodied creatures from the Brandon Bridge strata, Silurian in age, from southeast Wisconsin. The significance of this find is that it provides a first glimpse of the evolutionary record of soft-bodied animals after the Burgess Shale. The question, of course, as Gould might put it is; has the motor of evolutionary invention cooled down by the early Silurian, 120 million years after the Burgess Shale was layed down?

In order to answer this question, paleontologists will, as they did with the Burgess material, have to painstakingly describe the creatures and place them in anatomical relationships to other life forms. Surprisingly, there has been no rush to shoulder this task, even though Derek Briggs, one of the heros of Gould's story, was one of the first to see the collection laid out before him.

So what can be said about the Brandon Bridge Fauna seven years after its discovery? Do these creatures represent a true fauna, i.e., an ecosystem? After all it does seem that ecosystems are the significant evolutionary units.

We believe that there is evidence to support the arrangement that the animals of the Brandon Bridge were a bonafide ecosystem, organisms truly living together in a common space, linked by energy food chains. On a purely physical level many of the species were found in a substantial range of sizes. For example, one species of arthropod ranges from one centimeter to nine centimeters (figure 2, e.). Another member of the fauna, the creature that may be a true Gouldien oddball, ranges from two centimeters to possibly over twelve centimeters (figure 2, a.). The body designs in the fauna indicate that there are filter feeders, scavengers and predators, animals that swam, and animals that burrowed in the mud. This is evidence that the Brandon Bridge Fauna is an integrated community (figure 1,2 and 3).

As to the anatomical composition of the fauna there are some surprises. A reconstruction of the ecosystem would find graptolites and conularids (figure 3, d.) as some of the dominant life forms. Both are now considered to be extinct phyla, and neither was present in the Burgess Shale. On the other hand, sponges so common in the Burgess, are absent in the Brandon Bridge.

The shelly component of the Brandon Bridge Fauna is significant by its rarety. There were less than ten species represented in all: one nautiloid, one crinoid, a few brachiopods and no corals. Coral reef building was a major factor in the sea of this time and in many places of eastern Wisconsin it was common place. This would suggest that the shelly animals were not part of the Brandon Brigde ecosystem but were somehow transported into the area of preservation. In the only study to date of the Brandon Bridge Fauna, Briggs has described the earliest conodont animal, another of the extinct phyla found in the ecosystem.

Of the remaining species it would seem that most of them were either arthropods or worms of one kind or another. That has a familiar ring to it, as that was the initial claim for the Burgess shale animals too. Clearly all four major groups of arthropods mentioned in Gould's book are present including both soft and hard-bodied trilobites. More problematic are the various worm-like organisms. Some of these are quite remarkable (figure 3). Unfortunately, in most cases only a single specimen of each species exist. The animal we called "The Butterfly Animal" (figure 2, a.) is clearly a renegade arthropod or it is conceivable that it will not be shoehorned into arthropods at all and will have to stand as a phylum in its own right.

Overall, the appearance of the fauna has a fimilar feeling to it, things are not so strange as the Burgess Shale. Still, the animals are clearly not even like the creatures of today; nor do they even compare to those of the Mazon Creek Fauna which are much more modern in appearance. Are these animals the obvious winner of the Burgess Shale carp shoot? Nothing new seems to have come along to challenge their supremacy. Again it appears there are many losers, for most of the oddballs described in the Burgess Shale are not present in the Brandon Bridge Fauna. So, in the intervening 120 million years, the final dye seems to have been cast, eliminating all but the eventual winners.

What about the locality itself? Does it have secrets yet to be revealed? The quarry on the outskirts of Waukesa, Wisconsin is one of those wonderful places found throughout the eastern half of the United States.

When we started collecting, the quarry had already seen its better days. The amount of material that could have been collected during the operation of the quarry could have easily rivalled the Burgess Shale in sheer volume. When we arrived, there was a small knoll on the east side of the quarry remaining, as well as a ledge exposing about 140 square meters on the west side. Unfortunately, at the time, the west side ledge was being quarried. We were ultimately able to collect only ten percent of the material before the rest was blasted away.

That this material was blasted away was one of the worst paleontological losses of all times. It would have been easy for a large piece of equipment to lift up the fossil rich layers for later extraction of specimens. Indeed, for reasons unknown this precious material was allowed to become the foundation of some unknown highway.

This is particularly sad because we were always finding new creatures as we prepared the rock which we were able to salvage. After all, it is not often, that such a significant Lagerstatten is found.

What remains today is a small knoll of material on the east side. Even if this is carefully collected it seems unlikely to yield much that will be new, since the preservation of specimens on this side was markedly inferior to the west wall material. On the west side, the quarry has met its boundary; the fossiliferous layers are suspended high up in the middle of a 70 meter wall.

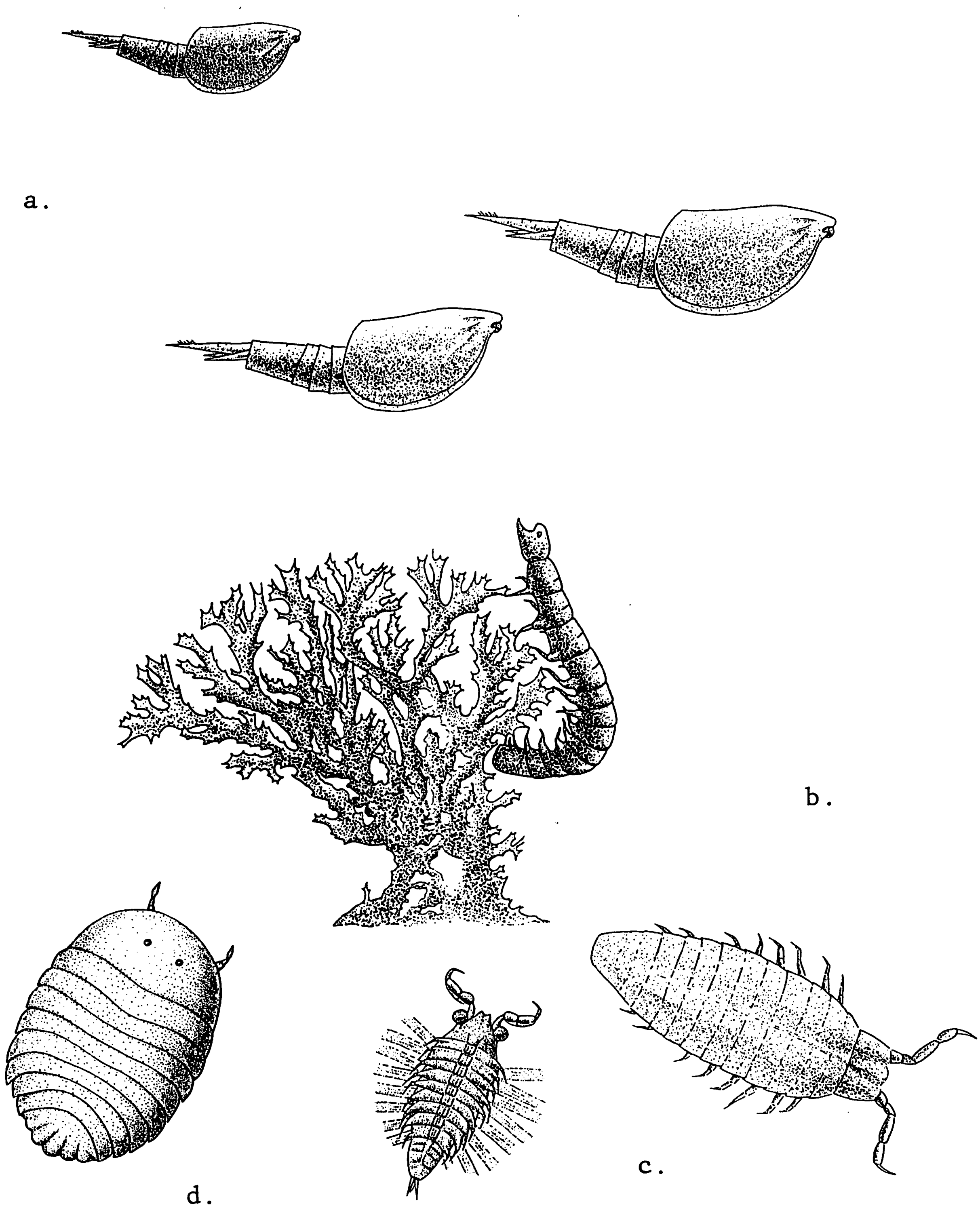


Figure 1: a. Phyllocarida; b. Myriapod-like, earliest known; c. two arthropods showing similarities to both branchiopods and remipede Crustacea; d. most recently discovered soft-bodied arthropod.

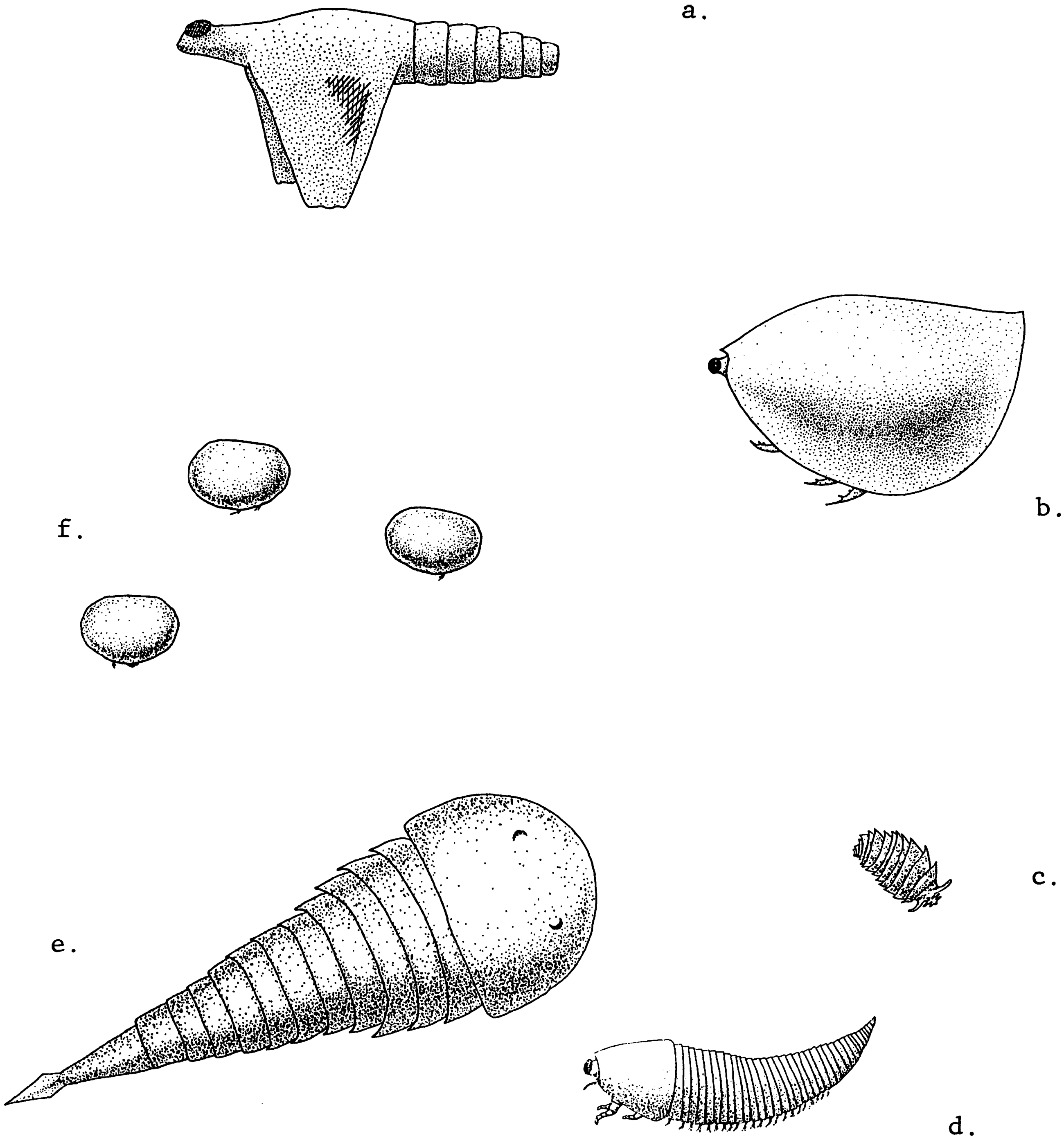


Figure 2: a. an oddball arthropod; b. an enigmatic bivalve arthropod, ?Crustacea; c. an undescribed arthropod less than a centimeter long; d. an arthropod with 30-40 divisions; e. the earliest completely preserved Xiphosurid; f. ostracods.

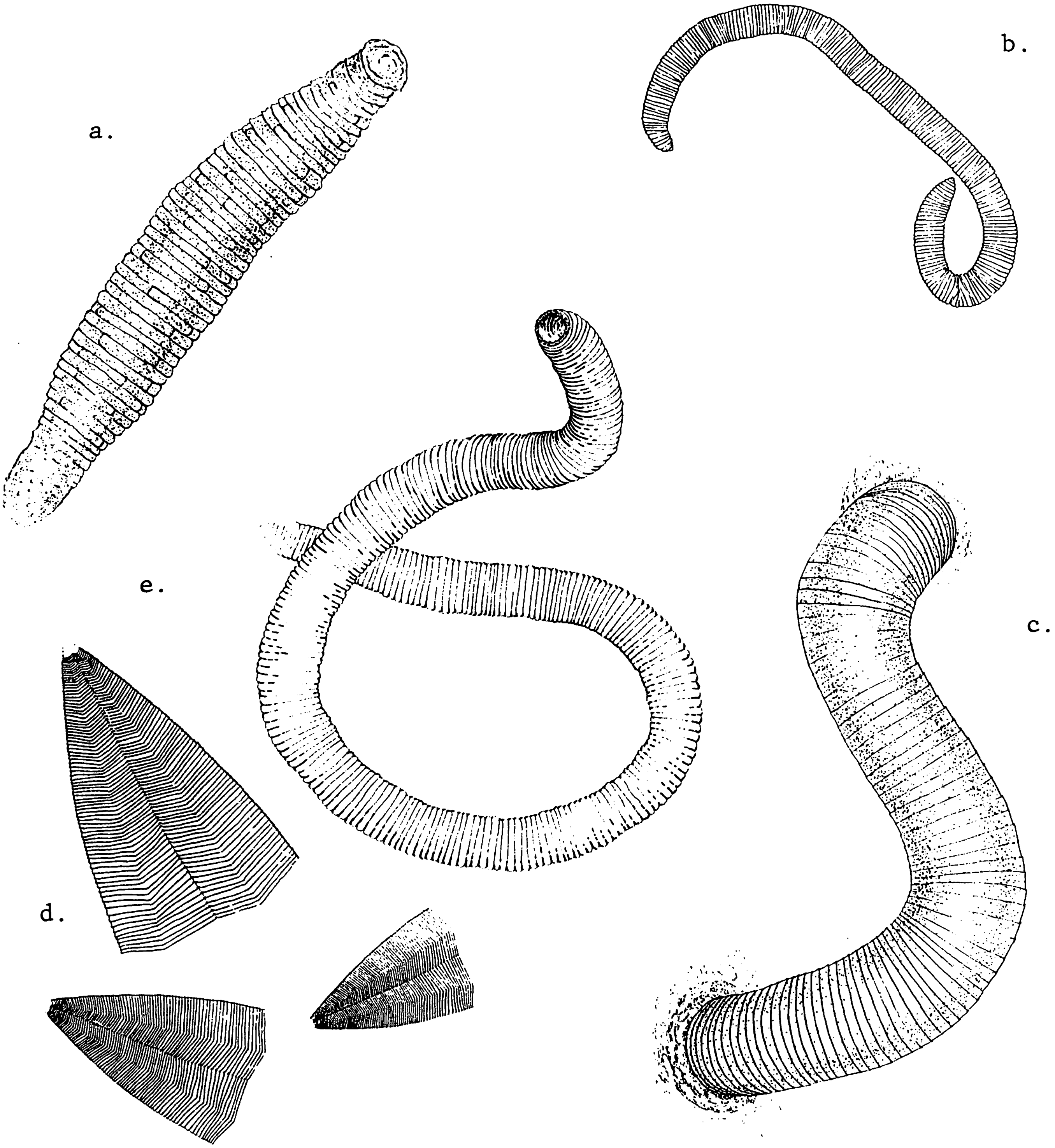
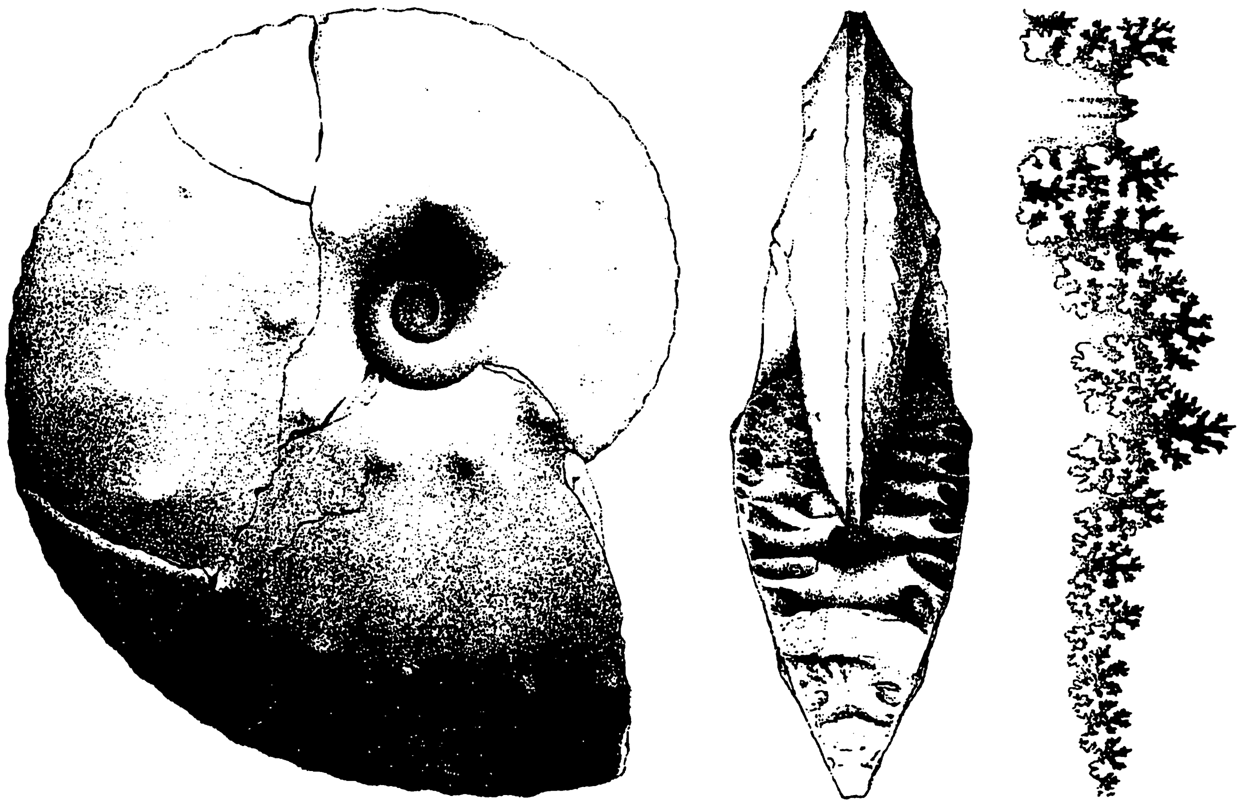


Figure 3: a. worm, reconstructed from a couple fragments; b. Papillate worm; c. worm, reconstructed from partially exposed specimen; d. Conularid; e. leech.

The Pierre Shale and Its Macrofauna

By: Peter L. Larson, Neal L. Larson and Robert A. Farrar
Black Hills Institute of Geological Research, Inc.



Placenticeras intercalare
(after Meek 1876)

Introduction

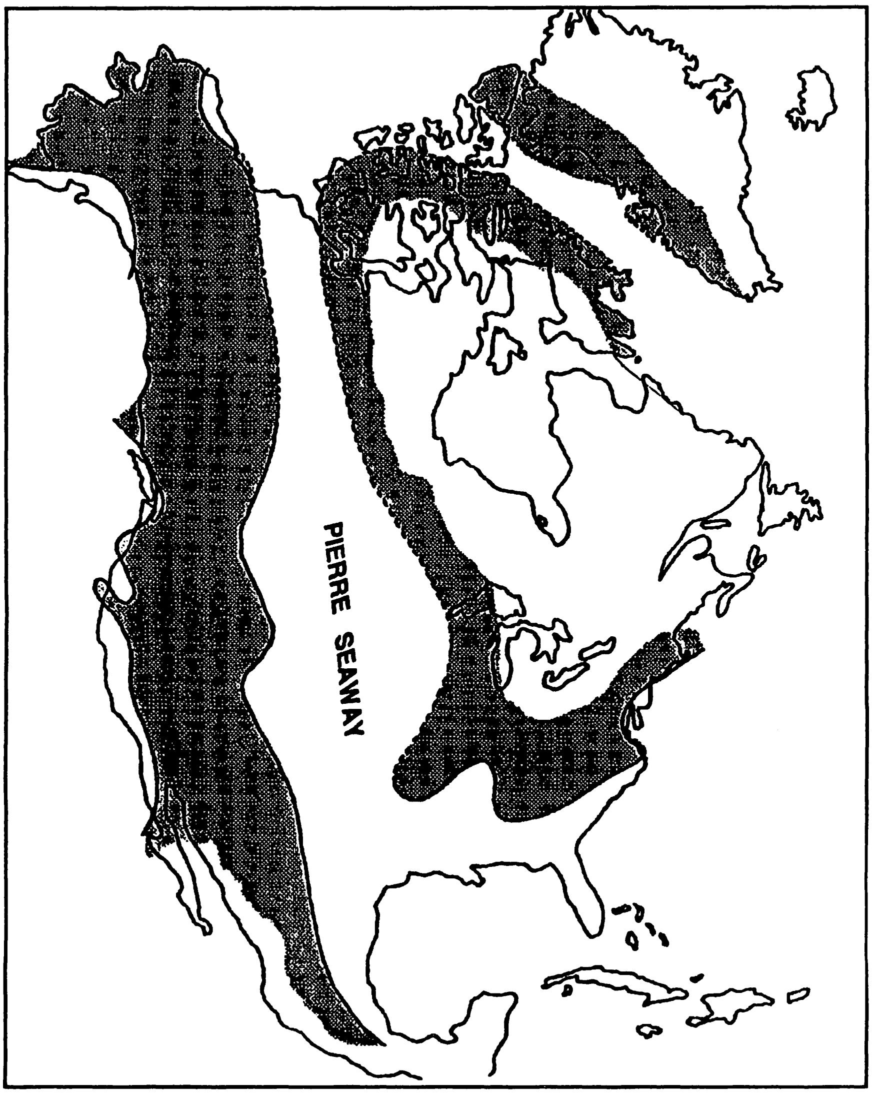
The Pierre Shale and its macrofauna have been studied for more than one hundred years. F. B. Meek collected, figured and described many of the common invertebrate fossils. His 1876 monograph, *Invertebrate Cretaceous and Tertiary Fossils of the Upper Missouri Country,* is the most comprehensive reference for Pierre Shale invertebrate fossils, to date. Since that time, many others have published works on the cephalopods, gastropods, pelecypods, arthropods and other invertebrates. A large variety of vertebrates have also been reported. Despite scores of publications on the geology and fauna, many specimens await description. The rapid erosion of the shale exposes more fossils each year and the continued collecting of this material will undoubtedly yield new taxa.

Age

The Pierre Shale formed near the end of the Mesozoic Era and is Late Cretaceous in age. Deposition began about 82 million years ago (Late Early Campanian stage) and ended about 67 million years ago (Middle Maestrichtian stage). Thus, the Pierre Shale preserves a fifteen million year record of ancient marine life.

Geographic and Geologic Setting

The Pierre Shale was deposited in a large inland seaway which, at times, stretched from the Gulf of Mexico to the Arctic Ocean. Water depth probably averaged less than 300 feet. This large epicontinental sea covered most of the Western Interior of North America. Exposures of the Pierre Shale outcrop in Alberta, Saskatchewan, Montana, North Dakota, South Dakota, Wyoming, Nebraska, Colorado, Kansas and New Mexico.



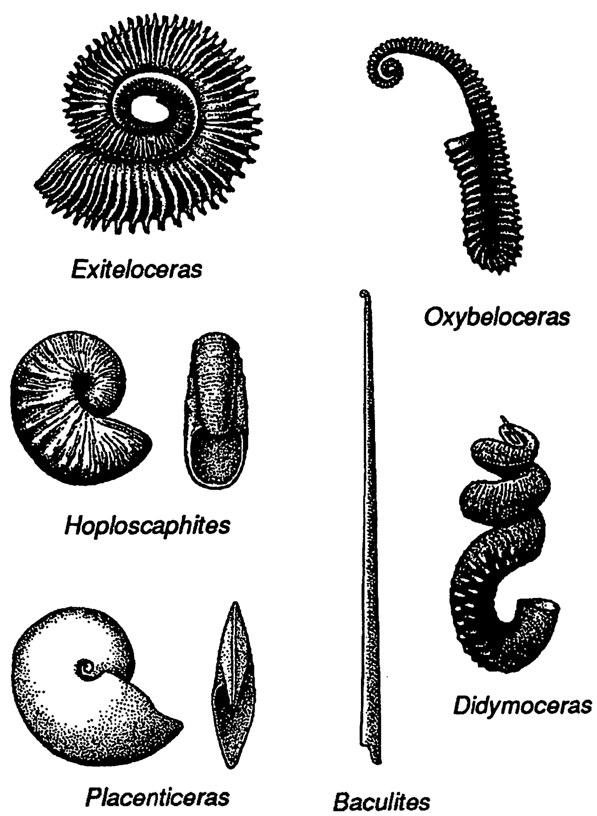
Ancient shorelines of the Upper Cretaceous superimposed on a modern map of North America

During Campanian and Maestrichtian times, fluctuations in sea level caused changes in the western (and presumably eastern) margins of the seaway. The western portion of the Pierre Shale is often intertongued with terrestrial deposits. One such terrestrial "tongue" is the Judith River Formation of Central Montana and Alberta. During Late Campanian times, the seaway again expanded to the west depositing the Bearpaw Shale in Montana and Alberta. The marine shales of the Bearpaw are the time equivalents of the upper Pierre Shale in the rest of the Western Interior. As the Cretaceous drew to a close, the Pierre Seaway also began to close.

The Pierre Shale rests conformably upon the Niobrara Formation, a yellow to gray, loosely cemented limestone or chalk. Deposited conformably on top of the Pierre Shale is the Fox Hills Formation. The Fox Hills Formation is a sandstone and sandy shale. It is time transgressive and was deposited at the edge of the seaway as it receded from the West to the East. Therefore, the top of the Pierre Shale in Wyoming is older than the top of the Pierre Shale in central South Dakota.

Invertebrate Macro Fossils

The Pierre Shale is probably best known for its remarkably well preserved ammonites. These include *Placenticeras* and a host of aberrant forms such as *Baculites, Hoploscaphites, Exiteloceras, and Didymoceras*. There are also a number of less known and a few undescribed ammonites. These are often found in great numbers and sometimes in an excellent state of preservation with iridescent nacre intact. *Eutrephoceras*, the ancestor of the present day chambered nautilus occurs frequently. Other cephalopods, such as belemnites and squids, are rare. Gastropods, pelecypods, and scaphopods commonly occur in abundance and are well preserved. Although these mollusks are usually best preserved in calcareous concretions, they also occur loose in the shale.



Ammonite Forms: Pierre Shale
Artist: Dorothy Sigler-Norton

Echinoderms are rare in the Pierre Shale, although several echinoid genera and a brittle-star have been noted. The echinoids usually occur in concretions but have also been found loose in the shale. One locality in South Dakota has produced complete ophiuroids which occur in compacted shale.

Arthropods are uncommon in the Pierre Shale, however, limited areas have produced abundant lobsters and crabs. Several localities in South Dakota produce small crabs in concretions (*Dakoticancer*). One site yields crabs and lobsters (*Linuparus*) in concretions and loose in the shale.

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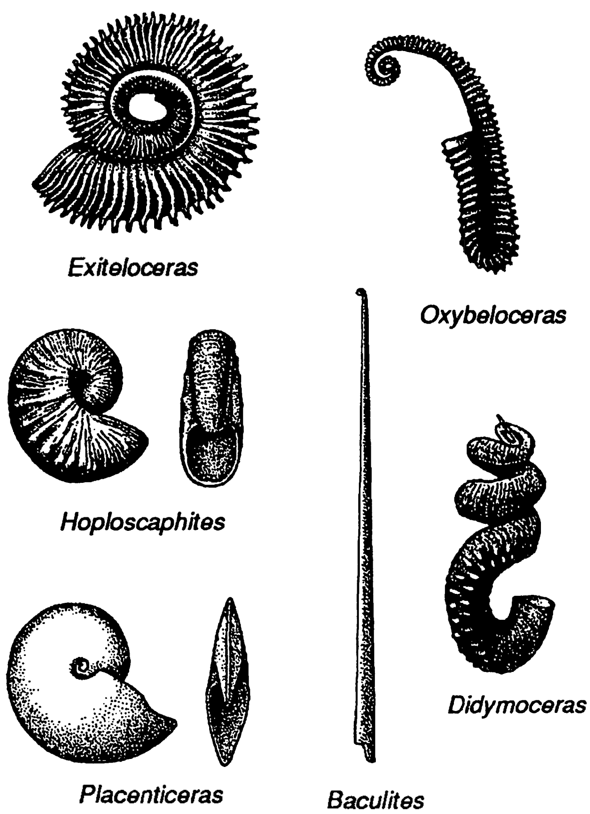
The Pierre Shale rests conformably upon the Niobrara Formation, a yellow to gray, loosely cemented limestone or chalk. Deposited conformably on top of the Pierre Shale is the Fox Hills Formation. The Fox Hills Formation is a sandstone and sandy shale. It is time transgressive and was deposited at the edge of the seaway as it receded from the West to the East. Therefore, the top of the Pierre Shale in Wyoming is older than the top of the Pierre Shale in central South Dakota.

Invertebrate Macro Fossils

The Pierre Shale is probably best known for its remarkably well preserved ammonites. These include *Placenticeras* and a host of aberrant forms such as *Baculites, Hoploscaphites, Exiteloceras, and Didymoceras*. There are also a number of less known and a few undescribed ammonites. These are often found in great numbers and sometimes in an excellent state of preservation with iridescent nacre intact. *Eutrephoceras*, the ancestor of the present day chambered nautilus occurs frequently. Other cephalopods, such as belemnites and squids, are rare. Gastropods, pelecypods, and scaphopods commonly occur in abundance and are well preserved. Although these mollusks are usually best preserved in calcareous concretions, they also occur loose in the shale.



Ammonite Forms: Pierre Shale
Artist: Dorothy Sigler-Norton

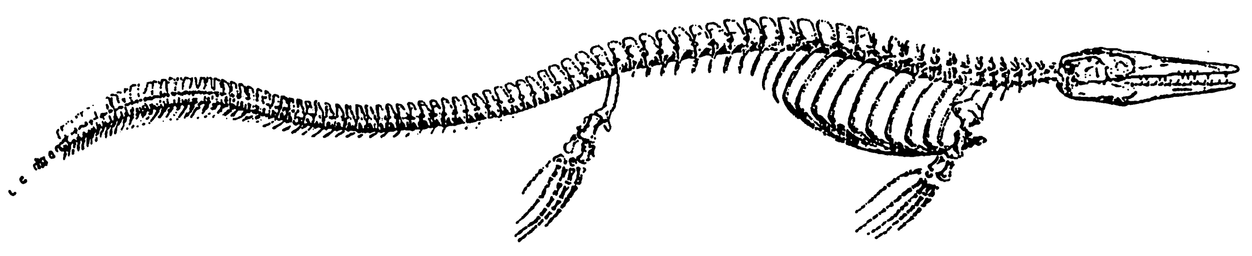
Echinoderms are rare in the Pierre Shale, although several echinoid genera and a brittle-star have been noted. The echinoids usually occur in concretions but have also been found loose in the shale. One locality in South Dakota has produced complete ophiuroids which occur in compacted shale.

Arthropods are uncommon in the Pierre Shale, however, limited areas have produced abundant lobsters and crabs. Several localities in South Dakota produce small crabs in concretions (*Dakoticancer*). One site yields crabs and lobsters (*Linuparus*) in concretions and loose in the shale.

A concretion horizon in the Bearpaw Shale (equivalent of the Upper Pierre Shale) in central Montana produces abundant lobsters of the genera, *Hoploparia, Palaeonephrops* and *Linuparus*. Other invertebrates of the Pierre Shale include bryozoans and brachiopods.

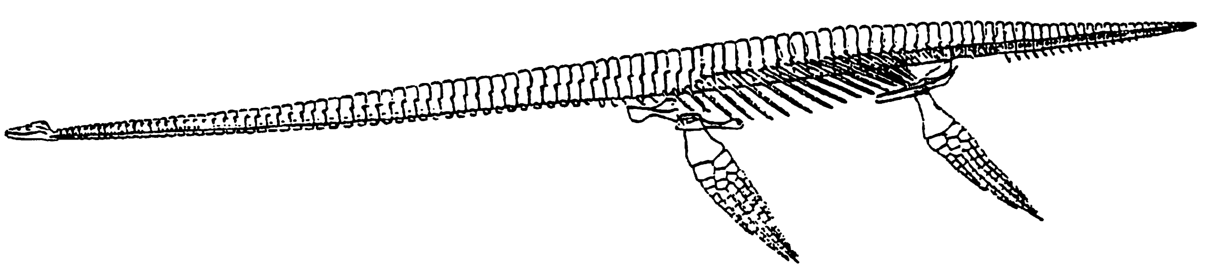
Palaeonephrops browni

Vertebrate Fossils



Tylosaurus proriger
(after Osborn 1899)

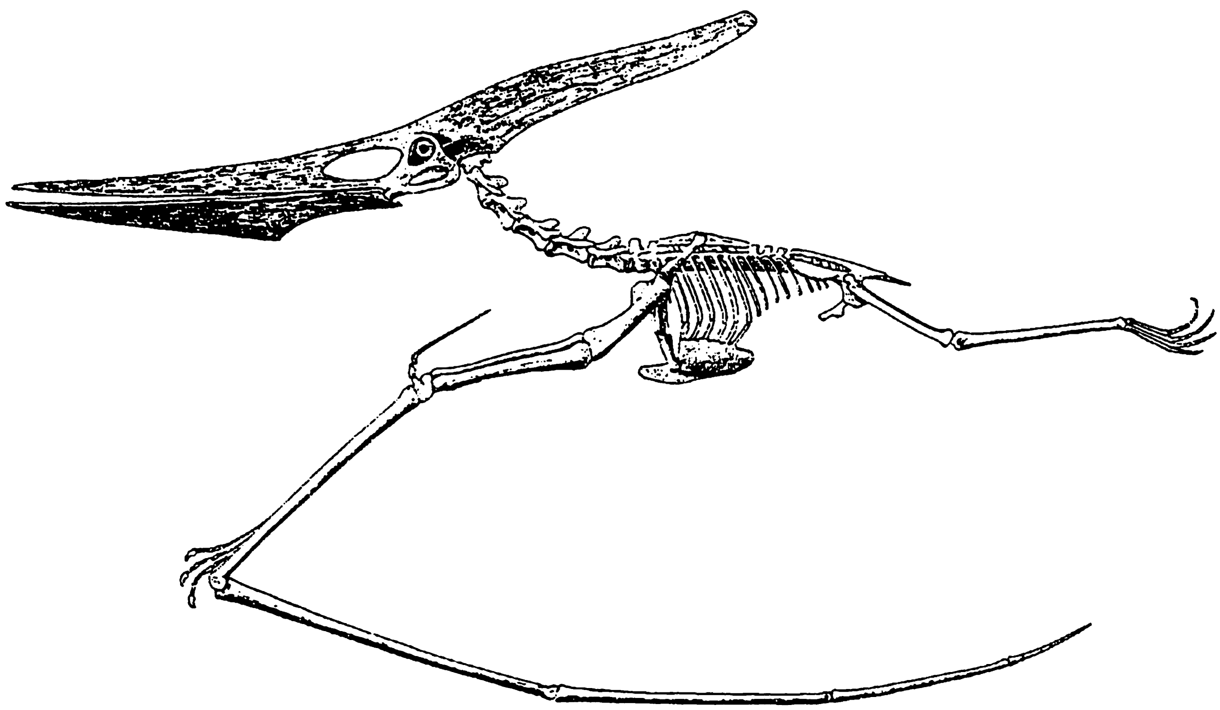
Vertebrate fossils are found throughout the Pierre Shale. They are preserved both in concretions and loose in the shale. Vertebrates are common only in the Sharon Springs Member low in the formation. Most of the specimens found in this horizon are poorly preserved. Consequently, excavation preparation and description of this fauna have been limited. Interest in this fauna has increased and extensive collecting projects have begun. Ken Carpenter of the Denver Museum of Natural History has been particularly active in researching this fauna. The documented vertebrates of the Pierre Shale include mosasaurs, plesiosaurs, pterosaurs, birds, turtles and fish. Dinosaurs are one of the more unusual faunal elements of the Pierre Shale, probably representing carcasses which were washed out to sea.



Elasmosaurid Plesiosaur
(after Welles 1943)

Conclusion

The fauna of the Pierre Shale is extremely rich and offers a view of life in the ancient seas. The vast exposures of the Pierre Shale throughout the Western Interior of North America provide a rich collecting ground for the professional and the amateur collector. Many exposures are located on private land and are accessible to all who secure permission to collect. Due to the abundance of fossils and the large areas of exposure, it is still possible to find undescribed species of invertebrate and vertebrate fossils. There are many scientific studies of this fauna yet to pursue. Through careful collecting and documentation, we will add to our knowledge of this important and interesting period of Earth's history.



Pteranodon ingens
(after Eaton 1910)

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MACROFAUNA of the PIERRE SHALE

PHYLUM ANNELIDA

Serpula cretacea
Serpula martimani
Serpula sp.
Omasaria sp.
Diploconcha sp.

PHYLUM ARTHROPODA

Class Crustacea

Order Decapoda

Eomunidopsis cobbani
Dakoticancer overanus
Necrocarcinus pierrensis
Raninella vaheensis
Sodakus tatankayotankaensis
Homolopsis punctata
Homolopsis mendryki
Hoploparia bearpawenisi
Linuparus pustulosus
Callianassa cheyennensis
Palaeonephrops browni

PHYLUM BRACHIOPODA

Class Inarticulata

Order Lingulida

Lingula subspatulata

PHYLUM BRYOZOA

Pyriporoid bryozoan
Membraniporoid bryozoan

PHYLUM COELENTERATA

Class Anthozoa

Order Scleractinia

c.f. *Websteria* sp.
Micrabacia americana
Trochocyathus sp.

PHYLUM ECHINODERMATA

Class Asteroidea

Order Echinoidea

Hemiaster humphreysia
Eurysalenia minima
undescribed species

PHYLUM MOLLUSCA

Class Cephalopoda

Order Ammonoidea

Anaklinoceras sp.
Anapachydiscus complexus
Anapachydiscus n. sp.
Baculites obtusus
Baculites aquilaensis
Baculites hagesi
Baculites obtusus
Baculites mclearni
Baculites asperiformis
Baculites perplexus
Baculites gilberti
Baculites gregoryensis
Baculites reduncus
Baculites pseudovatus
Baculites scotti
Baculites crickmayi
Baculites rugosus
Baculites compressus
Baculites cuneatus
Baculites reesidei
Baculites undatus
Baculites jenseni
Baculites eliasi
Baculites baculus
Baculites grandis
Baculites clinolobatus
Cirroceras sp.
Didymoceras mortoni
Didymoceras nebrascense
Didymoceras stevensoni
Didymoceras cheyennense
Didymoceras n. ssp.
Exiteloceras jennyi
Hoploscaphites gilli
Hoploscaphites romeri
Hoploscaphites landesi
Hoploscaphites c.f. *rugosus* ?
Hoploscaphites nodosus
Hoploscaphites n. ssp.
Jeletzkytes nodosus
Jeletzkytes furnivali
Jeletzkytes brevis
Jeletzkytes criptonodosus
Jeletzkytes crassus
Jeletzkytes plenus
Jeletzkytes tuberculatus
Menuites n. ssp.
c.f. *Parapachydiscus* sp.
Nostoceras aff. *N. humile*
Nostoceras aff. *N. columbriformis*
Oxybeloceras crassus
Oxybeloceras meekanum
Oxybeloceras n. sp.
Placenticeras meeki
Placenticeras planum
Placenticeras intercalare
Ponteixites graciles
Ponteixites robustus
Rhaeboceras subglobosus
Rhaeboceras c.f. *whiteavesi*
Rhaeboceras halli
Rhaeboceras albertense

Scaphites hippocrepis
Scaphites constrictus
Sphenodiscus (Coahuilites) sp.
Solenoceras texanum
Solenoceras mortoni
Solenoceras n. sp.
Trachyscaphites redbirdensis
Trachyscaphites spiniger
Trachyscaphites praespiniger
Order Belemnitida
Belemnitella bulbosa
Order Nautiliodea
Eutrephoceras montanense
Eutrephoceras dekayi
Eutrephoceras planoventer
Order Teuthidida
Actinosepia canadensis
Tusoteuthis sp.
Class Gastropoda
Acirsa (Hemiacirsa) n. species
Acmaeca occidentalis
Aceton c.f. *throckmortoni*
Akera ? sp.
Amuletum minor
Amauropsis ? sp.
Anchura haydeni
Anisomyon borealis
Anisomyon centrale
Anisomyon patelliformis
Anisomyuon subovatus
Anisomyon alveolus
Anisomyon sexulcatus
Anomia sp.
Anomalofusus ? sp.
Astandes densatus
Aporrhais biangulata
Atira ? nebrascensis
Bellifusus ? n. sp.
Belliscala ? n. sp.
Bullopsis aff. *B. cretacea*
Bullopsis n. sp.
Capulus spangleri
Cerithioderma n. sp.
Cerithiopsis (Cerithiella) n. sp.
Closteriscus tenuilineatus
Cryptorhytis cheyennensis
Cryptorhytis flexicostata
Cuspidaria moreauensis
Cuspidaria sp.
Cylichna c.f. *secalina*
Cylichna c.f. *incisa*
Drepanochilus evansi
Drepanochilus scotti
Drepanochilus nebrascensis
Drepanochilus obesus
Drepanochilus sp.
Ellipsoscapha occidentalis
Ellipsoscapha subcylindrica
Ellipsoscapha aff. *E. occidentalis*
Ellipsoscapha aff *E. subcylindrica*
Eoacteon n. sp.
Euspira obliguata
Fasciolaria ? gracilenta
Graphidula culbertsoni
Graphidula c.f. *alleni*
Graphidula c.f. *obscura*
Gyrodes c.f. *spillmani*
Gyrodes subcarinatus
Lomirosa n. sp.
Margaritella flexistriata
Medionapus ? sp.
Mesorhytis gracilenta
Nonacteonina sp.
Nonacteonina attenuata
Oligoptycha concinna
Oligoptycha sp.
Paladmete n. sp.
Polinices concinna
Polinices rectilabrum
Polinices sp.
Potamides n. sp.
Promathilda (Clathrobaculus) n. sp.
Pseudomaura paludinaeformis
Pseudobuccinum nebrascense
Pyrifusus ? sp.
Pyropsis ? sp.
Pyropsis ? n. sp.
Remera c.f. *stephensoni*
Rhombopsis ? sp.
Rhombopsis newberryi
Rhombopsis subturritus
Rhombopsis ? intertextus
Scobinodolus sp.
Serrifusus dakotensis
Spironema ? sp.
Tornatellaea cretacea
Trachytriton vinculum
Turritella ? sp.
Vanikoropsis nebrascensis
Vanikoropsis haydeni
Vanikoropsis tuomeyana
Volutoderma ? clayworthyi
Xenophora sp.
Class Pelecypoda
Agerostrea mesenterica
Anatina doddsi
Anatina sp.
Anomia flemingi

Anomia raetiformis
Anomia subtrigonalis
Anomia c.f. *argentaria*
Anomia sp.
Anomia n. sp.
Aphrodina ? sp.
Astarte gregaria
Astarte sp.
Cadulus obnutus
Clisocolus moreauensis
Corbula crassimarginata
Crassatella subquadrata
Crassatella sp.
Crassostrea glabra
Crenella c.f. *elegantula*
Crenella aff. *C. microstriata*
Crenella sp.
Cuspidaria grovensis
Cuspidaria variabilis
Cuspidaria moreauensis
Cuspidaria sp.
Cyclorisma ? sp.
Cylichna sp.
Cymbophora warrenana
Cymbophora canonensis
Cymbophora holmesi
Cymbophora gracilis
Cymbophora sp.
Cymbophora n. sp.
Diploconcha ? sp.
Dosiniopsis deweyi
Ethmocardium welleri
Exogyra costata
Exogyra sp.
Gervillia sp.
Goniamia americana
Goniamia sp.
Goriochasma stimpsoni
Idoneorca shumardi
Inoceramus pertenuis
Inoceramus oblongus
Inoceramus sublaevis
Inoceramus agkjakendensis
Inoceramus subcompressus
Inoceramus convexus
Inoceramus barbarini
Inoceramus sublaevis
Inoceramus sagensis
Inoceramus barbarini
Inoceramus tenuilineatus
Inoceramus canadensis
Inoceramus vanuxemi
Inoceramus furnivali
Inoceramus subcircularis
Inoceramus c.f. *proximus*
Inoceramus aff. *I. mclearni*
Inoceramus c.f. *nebrascensis*
Inoceramus (Endocostea) sulcatus
Inoceramus undescribed species
Inoceramus typicus
Inoceramus incurvus
Inoceramus c.f. *balchi*
Inoceramus fibrosus
Inoceramus sp.
Leda pittensis
Leda hindi
Legumen ellipticum
Legumen sp.
Lima pelagica
Limatula aff. *L. acutilineata*
Limopsis sp.
Lucina occidentalis
Lucina subundata
Lunatia sp.
Lunatia subcrassa
Micrabacca ? sp.
Micrabacca americana
Modiolus aff. *M. wenonah*
Modiolus uddeni
Modiolus meeki
Modiolus c.f. *wrighti*
Nemodon sulcatinus
Nemodon adkinsi
Nemodon eufaulensis
Nemodon sp.
Nonacteonima ? sp.
Nucula cancellata
Nucula planimarginata
Nucula nacatochana
Nucula (Pectinucula) n. sp.
Nuculana bisulcata
Nuculana evansi
Nuculana corbetensis
Nuculana corsicana
Nuculana sp.
Nymphalucina subundata
Nymphalucina occidentalis
Nymphalucina sp.
Nymphalucina n. sp.
Opertochasma cuneatum
Ostrea russelli
Ostrea glabra
Ostrea sp.
Ostrea plumosa
Ostrea c.f. *O. falcata*
Ostrea inornata
Ostrea c.f. *O. russelli*
Oxytoma haydeni

Oxytoma nebrascana
Pachymya ? aurandi
Panope berthoudi
Panope sp.
Pecten (Chlamys) nebrascensis
Pecten (Syncyclonena ?) simplicius
Pecten (Amusiam ?) c.f. *danei*
Pecten (Camptonectes) sp.
Periploma ? sp.
Perrisonota protexta
Phelopteria linguaeformis
Phelopteria sublevis
Pholadomya hodgei
Pholadomya sp.
Pinna lakesii
Pinna sp.
Protocardia rara
Protocardia subquadrata
Protocardia sp.
Pseudoptera ? sp.
Pteria petrosa
Pteria c.f. *parkensis*
Pteria linguaeformis
Pteria sp.
Solemga n. sp.
Spyridoceramus fibrosus
Syncyclonema halli
Syncyclonema n. sp.
Tancredia sp.
Tellina munda
Tellinimera scitula
Tenea sp.
c.f. *Tenuiptera* sp.
Thetiopsis circularis
Thracia n. sp.
Thyasira n. sp.
Veniella aff. *V. conradi*
Veniella sp.
Veniella humilis
Yoldia scitula
Yoldia evansi
Class Scaphopoda
Dentalium gracile
Dentalium pauperculum
Dentalium sp.

PHYLUM CHORDATA
Class Chondrichthyes
Order Euselachii
Ptychodus sp.
Cretolamna appendiculata
Squalicorax c.f. *kaupi*
unidentified shark
Class Osteichthyes
Order Pachycormiformes
Protosphyraena gladius
undescribed holostean
Order Ichthyodectiformes
Gillicus arcuatus
Ichthyodectes ctenodon
Xiphactinus audax
undescribed ichthyodectid
Saurocephalus lanciformis
Saurodon leanus
"Prosaurodon" pygmaeus
Order Osteoglossiformes
Bananogmius evolutus
Order Elopiformes
Pachyrhizodus caninus
Pachyrhizodus minimus
Order Beryciformes
Hoplopteryx sp.
Order incertae sedis
Apsopelix anglicus
Cimolichthys nepaholica
Enchodus petrosus
Enchodus gladiolus
Stratodus apicalis
Apateodus sp.
Class Reptilia
Order Chelonia
Toxochelys latiremis
Toxochelys browni
Archelon ischyros
Desmatochelys lowi
Order Plesiosauria
Dolichorhynchops osborni
Elasmosaurus platyurus
Styxosaurus browni
Alzadasaurus pembertoni
Order Squamata
Platecarpus tympaniticus
Platecarpus somenensis
Plioplatecarpus primaevus
Prognathodon crassarctus
Prognathodon overtoni
Mosasaurus missouriensis
Mosasaurus conodon
Clidastes propython
Globidens dakotensis
Tylosaurus proriger
Order Pterosauria
Pteranodon c.f. *sternbergi*
Order Ornithopoda
unidentified Hadrosauridae
Class Aves
Order Hesperornithiformes
Hesperornis regalis
undescribed hesperornithoform

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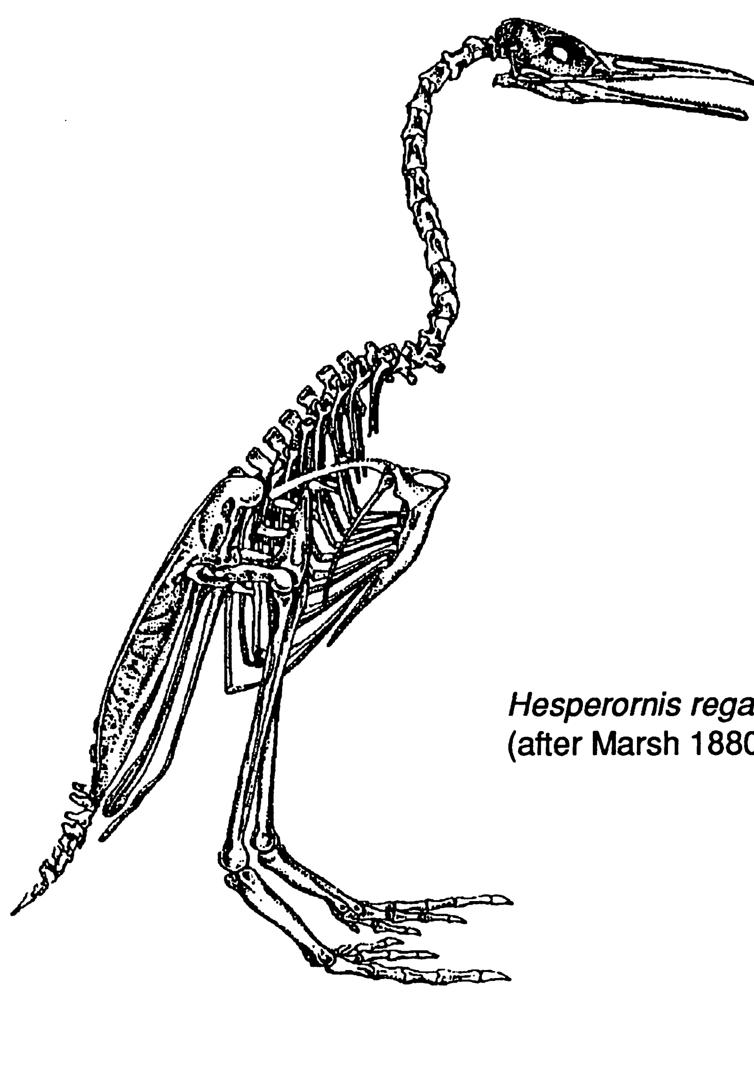

Hesperornis regalis
(after Marsh 1880)

THE LAGERSTATTEN OF THE WATERLIME OF NEW YORK AND ONTARIO

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By definition, Eurypterids are terrestrial and aquatic arthropods with a pair of preoral appendages located on the ventral side of the cephalothorax or prosoma (see figure 1). The extraordinary completeness and richness of this fossil in the Upper Silurian "Eurypterid Beds" began to unfold when the first specimen was found from Westmoreland, Oneida County, New York. In 1818 Dr. S. L. Mitchill incorrectly described this Eurypterus as a fossil fish of the genus Silurus; an error obviously induced by the catfish-like appearance of the incomplete carapace. In 1825, James DeKay recognized the arthropod nature of this fossil, for which he erected the genus Eurypterus and termed the species remipes. Eurypterids belong to the subphyllum Chelicerata, of the Class Merostomata Dana 1852, Subclass Eurypterida, Burmeister 1843, Superfamily Eurypteracea, Burmeister 1845, and Superfamily Stylonuracea, Diener 1924. Their bodies are divided into 3 segments: The prosoma, the preabdomen or mesosoma and postabdomen or metasoma. The mesosoma is composed of six tergites on the dorsal side and five sternites on the ventral side; the metasoma is composed of six caudal or postabdominal segments and a telson.

The subphyllum comprises the classes merostomata (Cambrian to recent), and arachnida (Silurian to recent). Where as the merostomes are aquatic forms, the arachnids are confined to land except for a few forms which are secondarily adapted to living in the water. It was proposed by Clarke and Ruedemann that these were one of the first animals ever to venture upon land. The different modes of life have significantly influenced the development of several morphological structures, especially the appendages (walking and swimming legs) and respiratory organs (gills and lungs).

Since fossil chelicerates are comparatively rare, our knowledge of the vertical and horizontal distribution of species is fairly limited. The vertical distribution of the paleozoic orders is shown in figure 2. As for horizontal distribution, merostomes are known from North and South America, Europe, Africa, Asia and Australia though more frequently in the northern rather than the southern hemisphere. Up to now fossil arachnids have been found almost exclusively in Europe and North America. An aerial extent of eurypterid localities in North America is shown in figure 3.

Anyone who has collected a fossil locality or a specific formation for a longtime, really gets to see some of the splendid varieties of fauna and flora that can be brought to light. Some of these localities are considered to be sparse of fossils or producing only one or two types and nothing else. This is the case in many of the exposures of the Siluraian dolostones of the Niagara escarpment; but in a few localities where the habitat of the Eurypterida is preserved in the Bertie waterlimes some of the most spectacularly preserved specimens can be found. The beds of the Bertie waterlime have for over 170 years yielded many very prized and splendid examples of Eurypterus, Dolichopterus, and a number of other plants, algae, graptolites, ostracods, cephalopods and phyllocarids. Many known only through their respective fragmentary remains, have been found and described by ardent amatuers and professionals alike over the years. The two most famous "Eurypterid pools" are located in the Buffalo area and in southern Herkimer county. No doubt these colonies were in part breeding pools from brackish to fresh waters closely associated to lagoonal and lacustrine environments prevalent at that time.

It was concluded by O'Connell (1916) that "the eurypterids throughout their phylogenetic history lived in the rivers". Others have proposed a more varied intertidal environment as the primary habitat of the eurypterids. As seen in central New York the underlying Camillus shales were deposited in shallow lagoons and extensive playa lakes and sabkha-like environments, with the occasional influx of sea water to which lime-muds were added by streams draining areas of eroding limestone throughout the New York -Ohio -Pennsylvania and the Michigan -Ohio basins, leading to the environment that the Bertie waterlime was deposited in and the extraordinary preservation of eurypterus and its associated faunas. These lagoonal and playa lake conditions are exemplified by the presence of mud-cracks and salt-hopper drag marks, cross laminations and channels in the limestones, dolostones and argillaceous limestones. This and the presence of eurypterids and ostracods would indicate that the waters in all were probably shallow.

Ruedemann believed that "while the Bertie waterlime does not contain a typical marine fauna, the scarcity of forms may be due to the early and complete dissolution of the aragonite shell in the dolomitic mud". This suggests that the Bertie was deposited in a lagoon behind barriers and coral reefs that were subjected to progressive deepening of the water. Todate evidence suggests that eurypterids inhabitied an intertidal environment ranging from just above high tide to a depth between the shore at low tide and about 50 meters or less. They probably lived in a restricted environment such as shallow lagoons with one or two tidal channels or breaches through a reef or barrier bar to the sea and through the inland boundary of the lagoon being associated with swamp areas and flats of an inland deltaic basin system. My opinion is that where these fossils have been found the water could not have been more than 1 meter (3 feet) deep.

I reached this conclusion after extensive excursions and work in the area. The locality that I am most familiar with is in southern Herkimer County at a road cut called Passage Gulf; here exposures of the Phelps waterlime provide some of the most exquisite eurypterid remains. It was construction of a road up the sides of a glacial valley that exposed the Fiddlers Green formation in the early 1950's, since then many spectacular specimens have been collected. Unfortunately due to the limited extent of the roadcut, collecting is very difficult due to the steepness of the sides. In 1984 Allan Lang, who purchased the property in an adjacent creek to collect these wonderful fossil creatures, began enlarging the exposure of the Fiddlers Green formation - specifically the Phelps waterlime (see section A) to an extent that has never been seen and in which some of the world's rarest fossils are being preserved. My first trip to the quarry as by Allan's invitation back in 1986, when for the first time I'd excavated, collected, studied and prepared the eurypterid fauna of this New York state formation. To my delight, I subsequently experienced first-hand the opening of a few pages of a late silurian benthic environment in the Herkimer pool.

Since it's discovery, many spectacular specimens of eurypterus have been found, with sizes ranging from 8 mm (.3 inches) up to 28 cm (1 inch), with pterygotus ranging from 15 cm (6 inches) to well over 1 meter (3 feet plus). Some body parts found would indicate a creature of about 5½ feet in length, as well as dolichopterus and proscorpius including a significant number of plants, algae, graplolites, phyllocarids, ostracods, cephalopods, and many other unidentified specimens (see figures 4, 5 and 6). The fossils themselves are preserved in the lower 2 to 3 feet of the Phelps waterlime and found in "wind rows" - which are actually very shallow, elongated troughs 3 inches to over 3 feet wide and five or more feet long in dolomitic muds of the lagoonal seas prevalent along what is now New York and Ontario. Typically we have an excavator dig into the slope to extract large blocks of the Phelps. Some of the rock will break open as the excavator pulls them out, occasionally showing some fossils; on others we hope to spot fine cracks on the edges of the rock along weathering planes, a zone of weakness which would indicate a fossil or a layer of parts and fragments and other unrecognizable blobs. The cracks are then split with thin wedges and chisels, the cap of rock then flipped over to reveal positive and negative impressions of the fossils. Back in the workshop the eurypterid is trimmed, thinned to a managable size, and if any of the fossils don't break properly and parts stick to their counterparts they are carefully removed and transferred when necessary and possible.

In general, the Bertie formation of New York and Ontario is a very hard dolomite of the quality that enables farm fences to last for centuries. Many localities produce eurypterid parts like swimming paddles, heads, turgites, and telsons that are fascinating to find - along with the chance to find a complete specimen. A few formations that have an abundant variety of silurian fossils are Ermosa, Bertie or Bass Island formations of Ontario, along with the Shawangunk grit and the Bertie or Schenectady of New York.

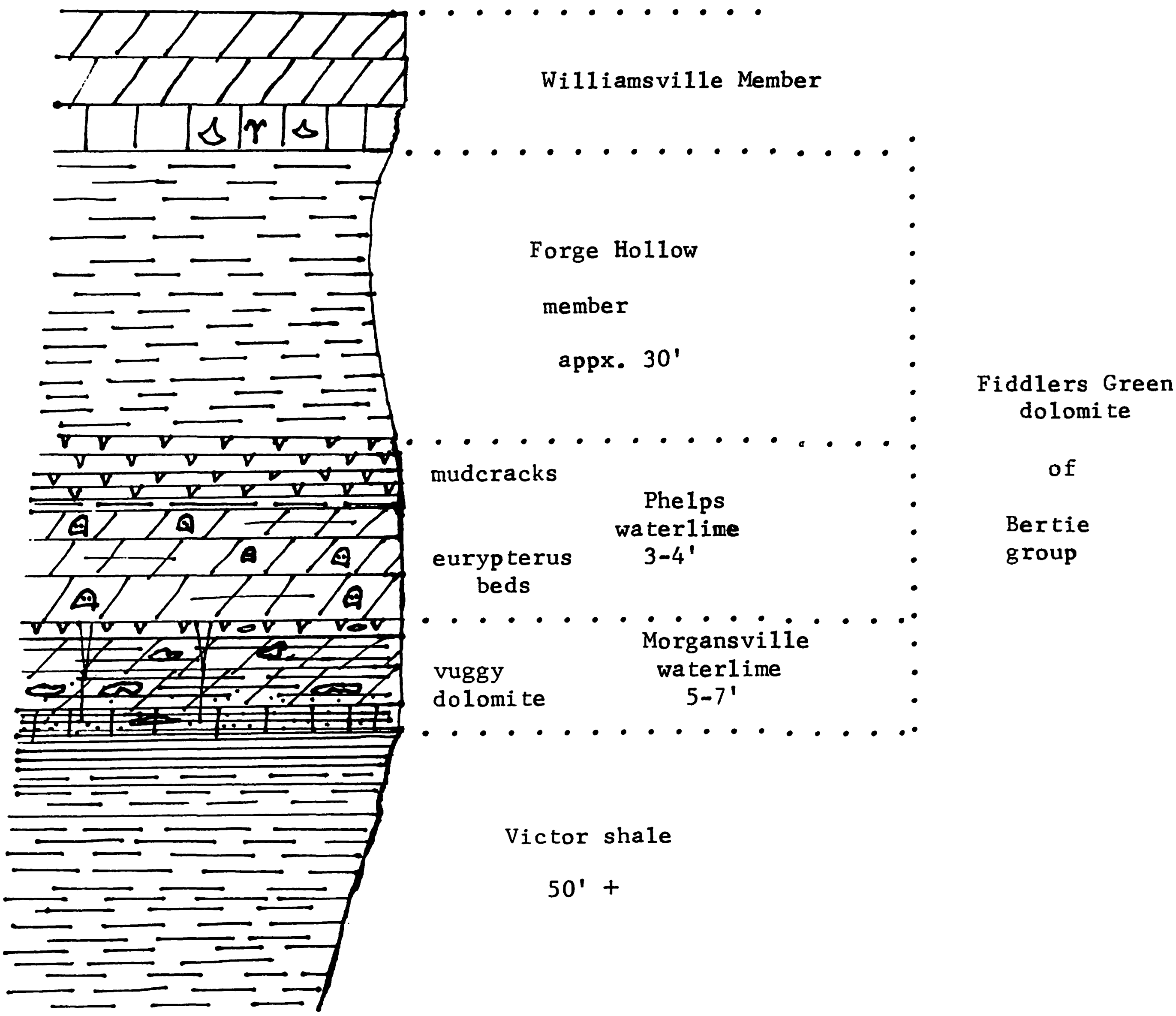


Figure A

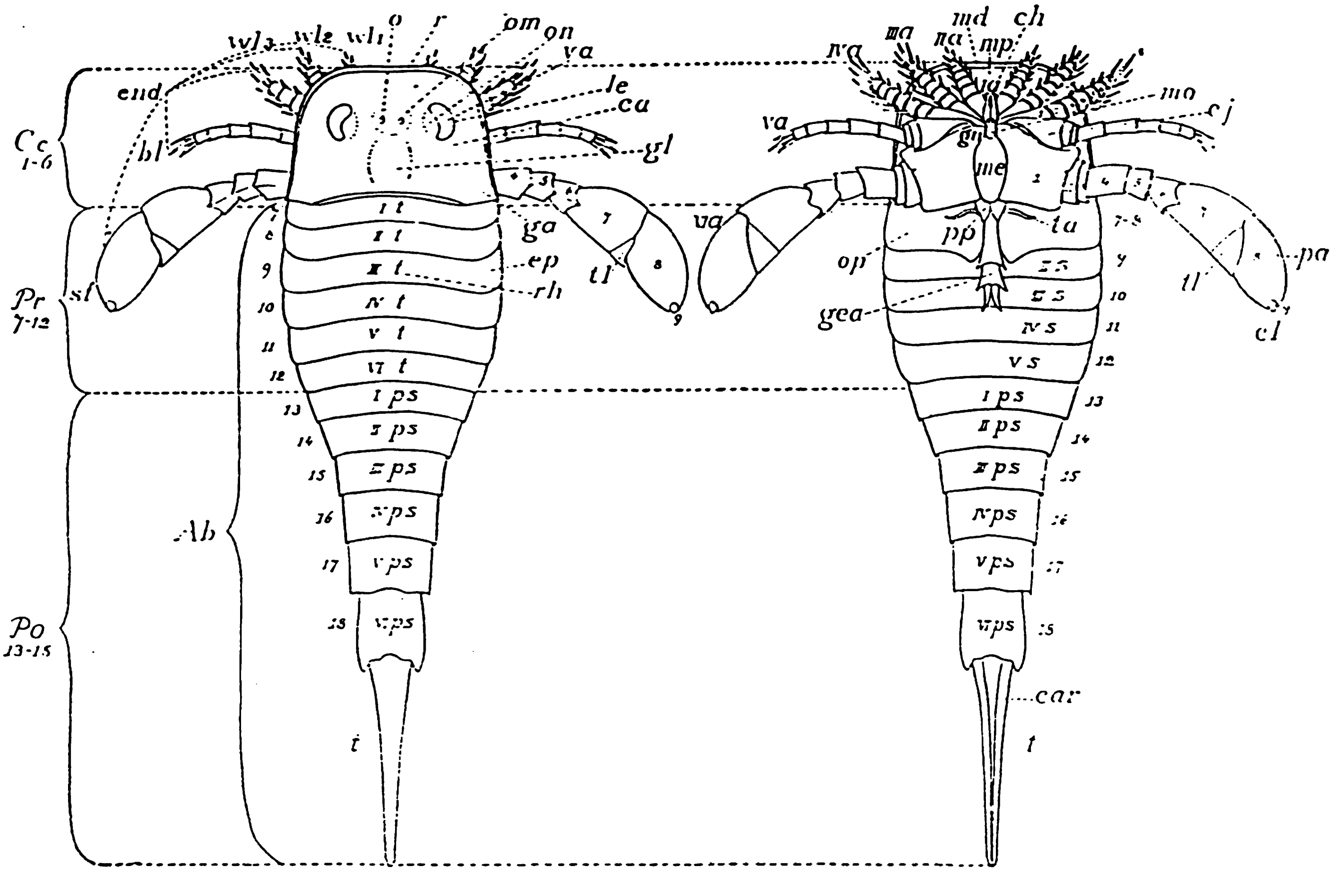


Figure 1 Diagram of an Eurypterid

a; Ia–VIa = appendages or legs
Ab = abdomen
bl = balancing leg
ca = carapace or head shield
car = carina of telson
Cc = cephalothorax or prosoma
ch = chelicerae, *Ia*, preoral appendages or mandibles
cj = coxa
end = postoral appendages or endognathites
ep = epimera or pleura of tergite
ga = genal angle
gea = genital appendage (female)
gl = glabella
gn = gnathobase
le = lateral or compound eyes
md = marginal doublure
me = metastoma or postoral plate
mo = mouth
mp = marginal plate on under side of cephalothorax
o = " larval " median eyes or ocelli
om = ocellar mound
on = ocular node
op = operculum or first sternite
pa = palette
Po = postabdomen or metasoma
pp = pentagonal pieces
Pr = preabdomen or mesosoma
ps, I–VI = caudal or postabdominal segments
r = rim
rh = rhachis
s, II–V = sternites
sf = swimming leg
t = telson
t, I–VI = tergites
ta = tubular organs
tl = triangular lobes
va = visual area
wl 1–3 = walking legs

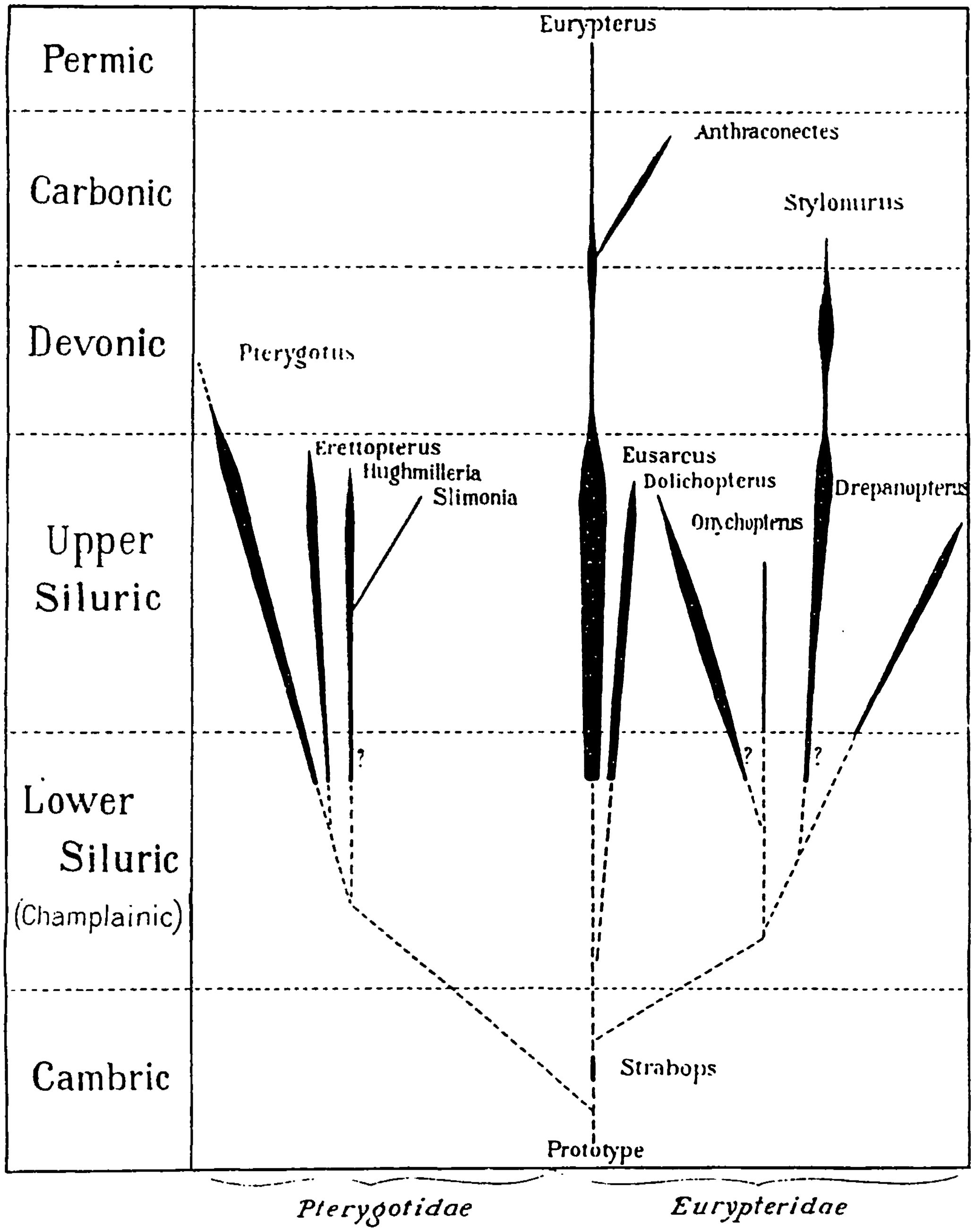
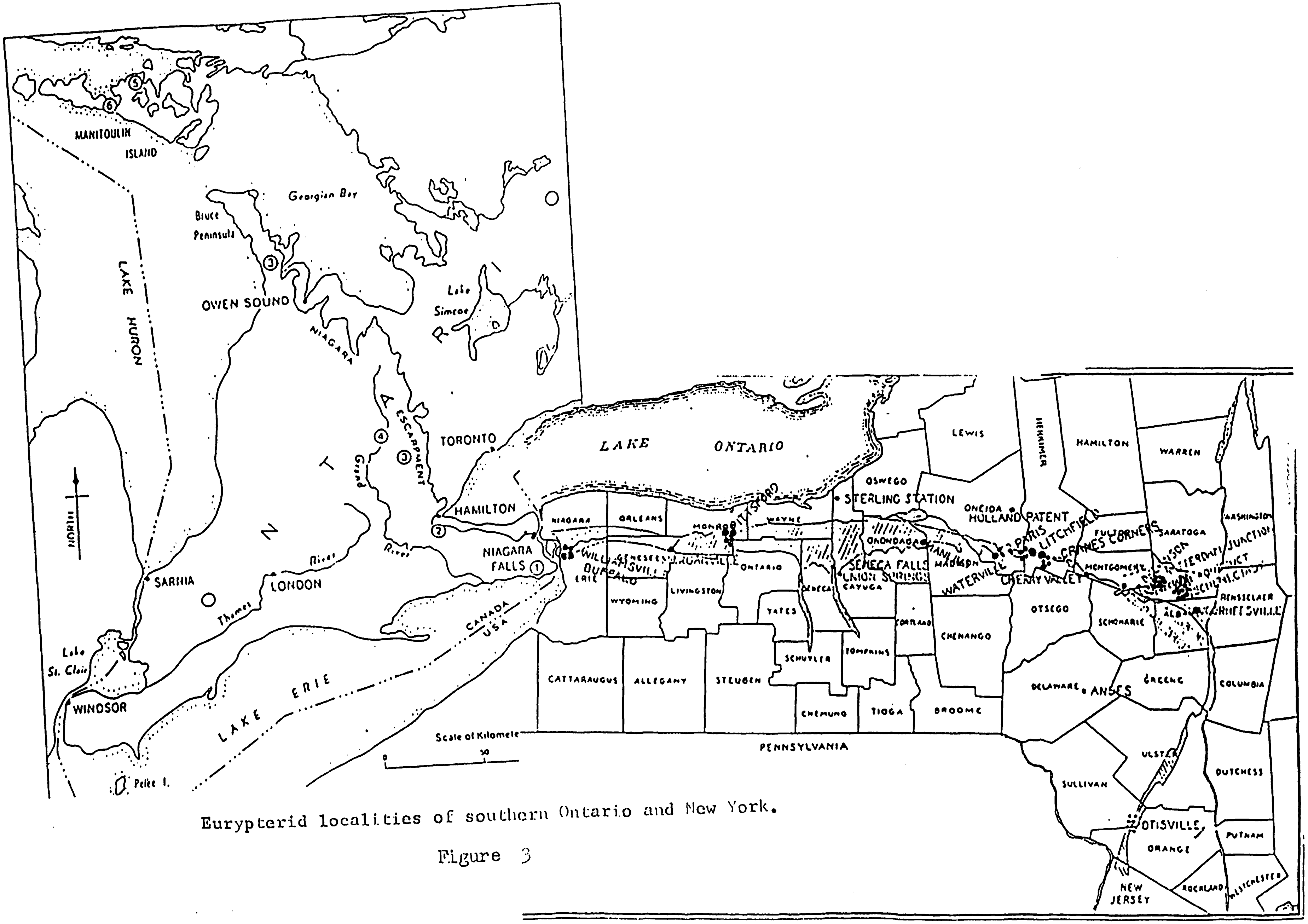


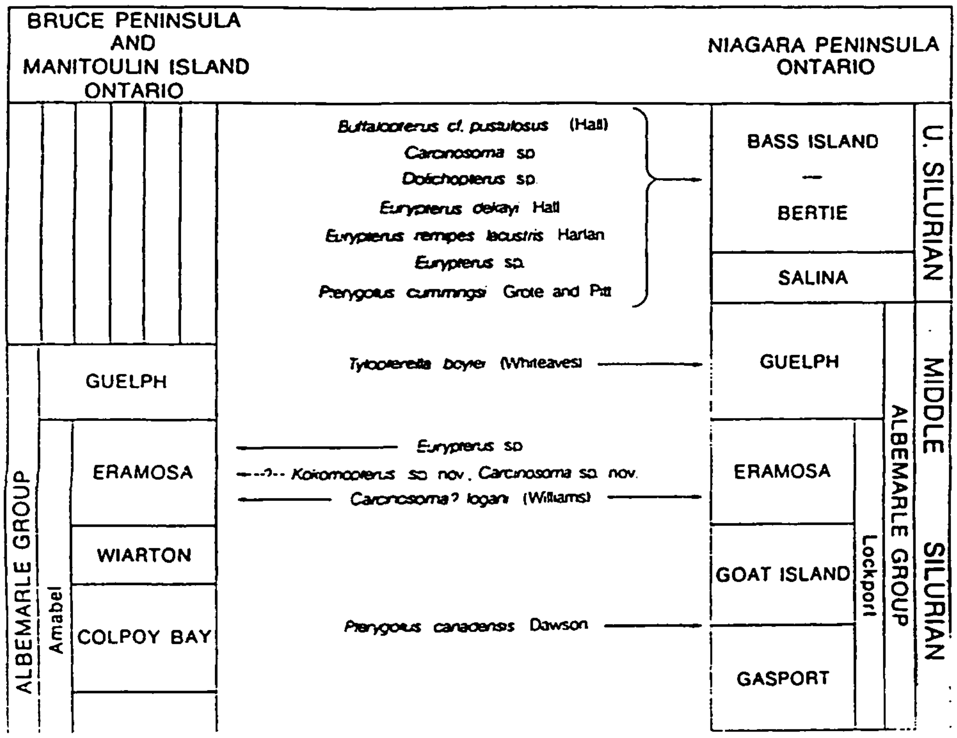
Diagram of the phylogeny and geological distribution of the genera of eurypterids

Figure 2



Eurypterid localities of southern Ontario and New York.

Figure 3



Stratigraphic distribution of eurypterids in southern Ontario.

Silurian.	Cayugan.	Eurypterid beds	Manlius limestone. Rondout waterlime. Cobleskill (Akron) dolomite. Salina beds: Bertie water lime, Camillus (Brayman?), Vernon, and Pittsford shales.
	Niagaran.		Guelph dolomite: Upper Shelby. Lower Shelby. Lockport dolomite, including Gasport limestone near base. Clinton beds: Rochester shale, Irondequoit limestone, Williamson shale, Wolcott limestone, Sodus shale, Reynales limestone, Furnaceville iron ore, Brewer Dock beds, Maplewood shales, Thorold sandstone (Oneida conglomerate).
	Medinan.		Albion: Grimsby sandstone. Cabot Head shale. Manitoulin beds. Whirlpool sandstone. Queenston shale.

Stratigraphic distribution of eurypterids in New York.

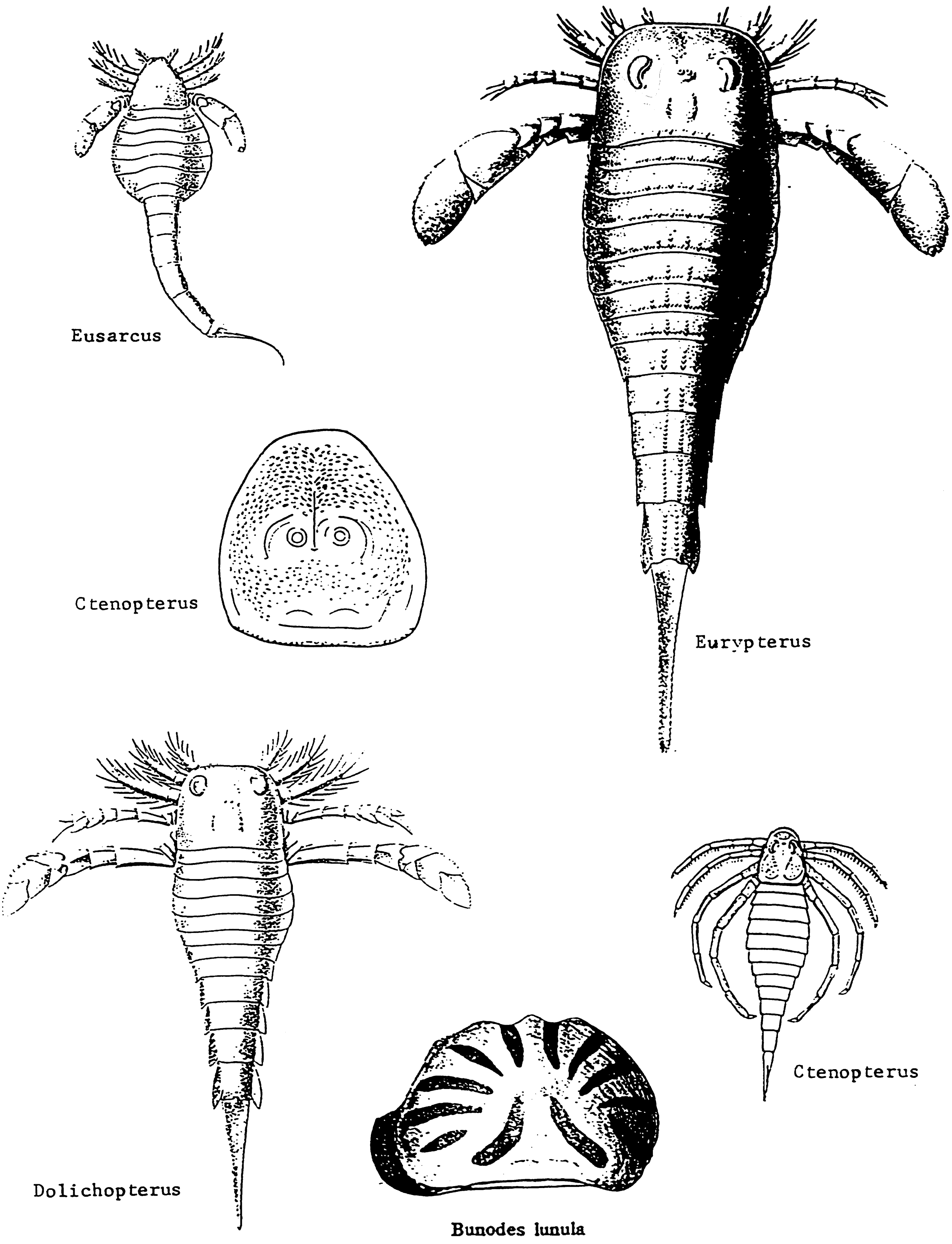

Eusarcus
Eurypterus
Ctenopterus
Dolichopterus
Ctenopterus
Bunodes lunula

Figure 4

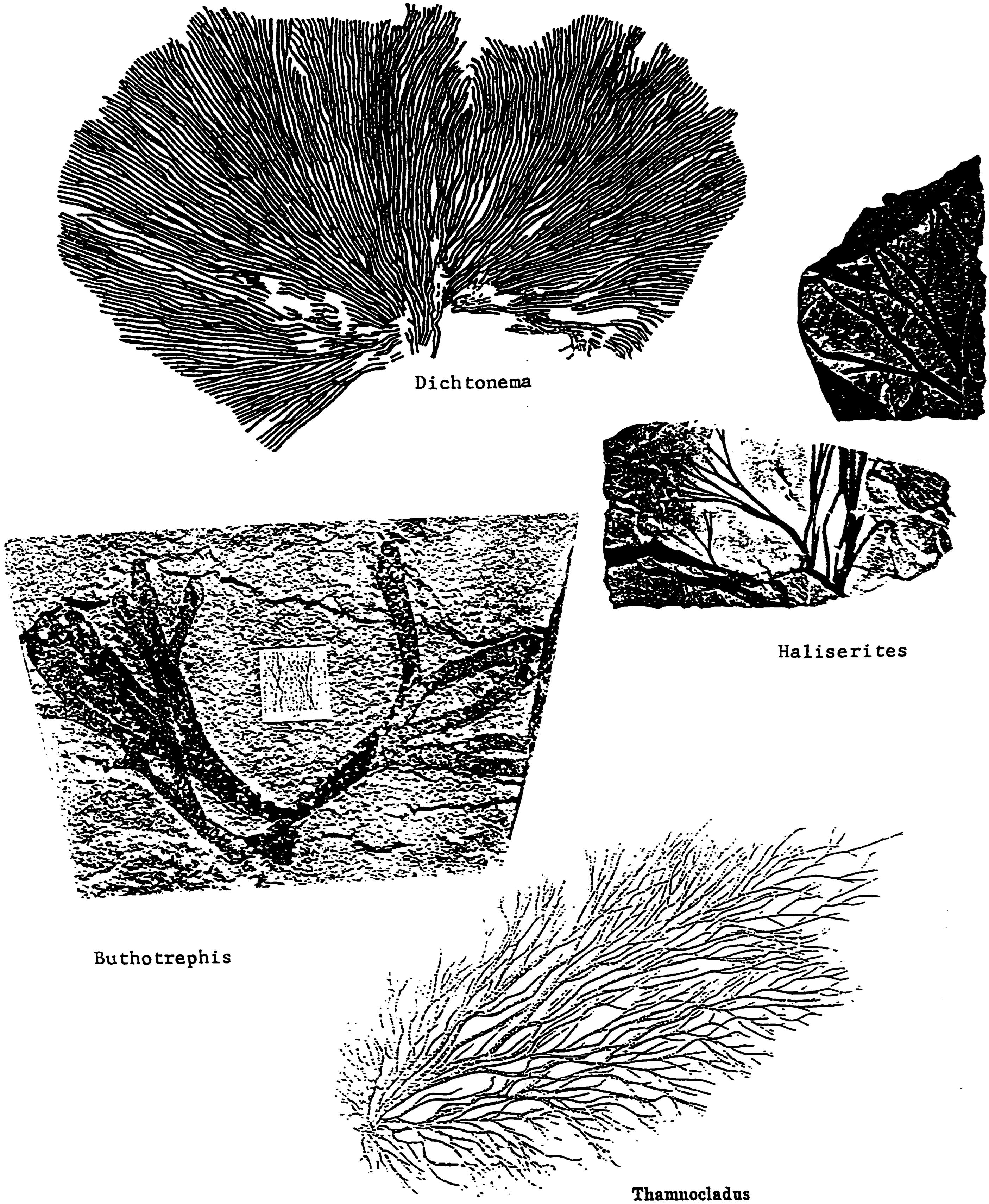
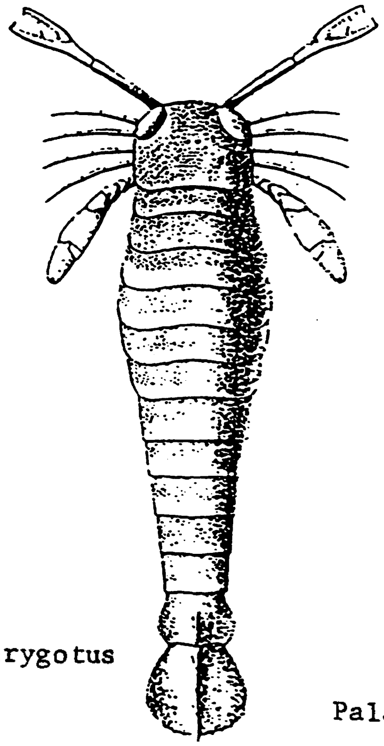
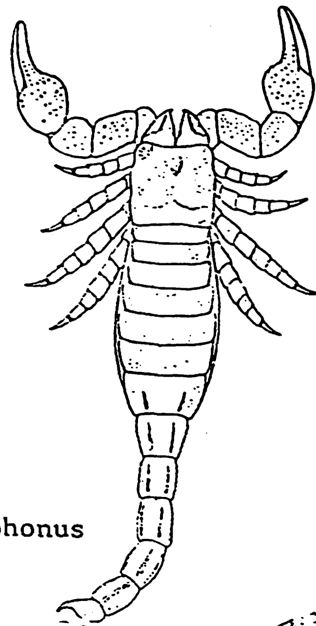


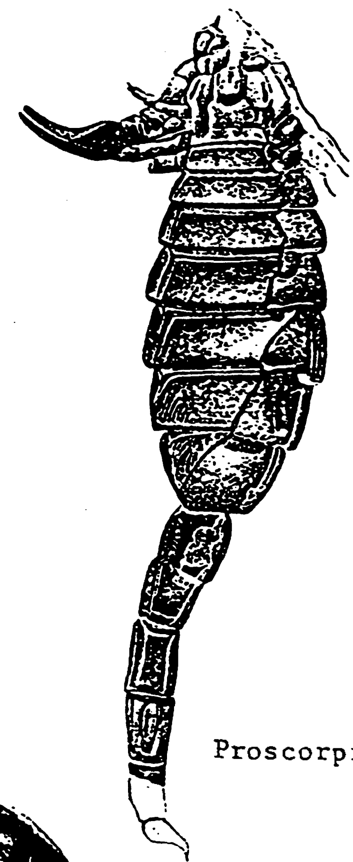
Figure 5



Pterygotus

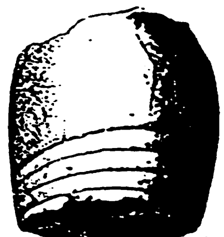


Palaeophonus



Proscorpius

Bunaia woodwardi



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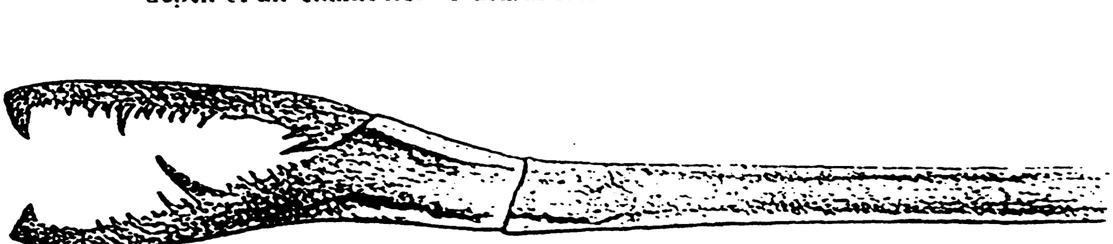
7

8

Hexameroceras chadwicki

Figs. 7, 8 Two views of type specimen. Natural size

Fig. 9 Lateral view of cotype, showing length of living chamber and depth of air-chambers. Natural size



Pterygotus chelicerae

Figure 6

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MONTGOMERY COUNTY INDIANA CLASSIC CRINOID SITES

THE EDWARDSVILLE FORMATION AT CRAWFORDSVILLE AND

THE RAMP CREEK FORMATION ON INDIAN CREEK

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HISTORY

In a western portion of central Indiana some of the finest preserved crinoids and associated fauna in the world are found. They occur in the Edwardsville and Ramp Creek formations.

Edward Hovey, a founding father of Wabash College in Crawfordsville is given credit for the first discovery of crinoid stems in the 1830's. At this time, Indiana was the western frontier. Sometime in the 1840's, Horace the son of Edward found a water-worn calyx of a crinoid. The boy thought this strange looking thing to be a petrified toad. As it turned out, this was probably the first crinoid calyx found in the area. This specimen is now deposited in the Field Museum of Natural History, Chicago, Illinois.

By the 1850's, there was a frenzy of activity as the locals found and dug very complete crinoids. The specimens were sold to scientists who were in great competition with one another to publicize the new species first. The more descriptions of species a person wrote, the higher up the professional ladder he went in the 1800's.

The prize quarry spot was just north of Crawfordsville on Sugar Creek. This area is still known as Corey's Bluff, named after O. W. Corey, a local man and a zealous collector. He sent important specimens to Sidney Lyon and S. A. Casseday who published descriptions of the first crinoids from Montgomery County, Indiana. In later years, 1880-1906, the Bluff was exploited by Paul Mohr known as a "friend of science" and his partner, Frederick Braun, a professional collector. Later Braun also collected for Frank Springer, one of the top crinoid specialists ever to live.

Daniel Bassett, an agent for the Wabash College, bought part of the Bluff and quarried out specimens that were sold to Museums and institutions around the world. Bassett was probably the first person to collect large slabs with complete crinoids; crowns, stems and holdfast.

These slabs showed the association of the various fossils. He was also one of the better preparators of those days.

After 1906, during Brauns last dig at the Bluff, it was drilled and blasted, evidently to seal off any future collecting.

NEW ERA

For over half a century Corey's Bluff slumbered without quantities of crinoids being taken from her bank. Perhaps an occasional crown by some surface collector or mushroom hunter was all there was to be found.

In 1958, Dr.N. Gary Lane then Associate Professor at the University of California in Berkeley discovered a large collection of Crawfordsville crinoids in the University Museum. Little work had been done on these crinoids. Lane obtained permission to study this collection and published on it. The crinoids in this collection were collected by Bassett in the late 1880's.

Dr. Lane spent summer months in 1963 looking for crinoid bearing beds in the Crawfordsville area. In 1964, Dr. Lane did a vertical and lateral dig through the layers of the Bluff. From this, much was learned about the paleoecological association of fauna. Layer by layer the site was studied. Never before over the Bluff's long history had such a study been done. Before it was studied by specimens in hard or a cluster of specimens collected at different times by different collectors from different places. So the work yielded descriptions of various species and no paleoecology. This had gone on for over 100 years until Dr. Lane's work in 1964-65. At the present time the Bluff has been purchased by commercial collectors with little, if any, interest in the scientific aspect of this classic location.

Just as it did over one and one-half centuries ago, fossil sites in Montgomery County, Indiana draw men of various attitudes and interest in crinoids. Some are devoted, unselfish with scientific interest. Others seek scientific recognition or financial gain. Some are informed amateur paleontologists and professional collectors.

INDIAN CREEK

In 1888, Beachler, another professional collector, while in the employment of Frank Springer, found crinoids on Indian Creek. This site became known as Beachler's Great Nest. The Indian Creek occurence is stratigraphically younger than the beds at the Corey's Bluff site. The rock is somewhat harder and has a higher sand content.

Dr. N. Gary Lane rediscovered Beachler's Great Nest in 1966 after researching some of Springer's papers at the U.S. National Museum of Natural History.

This location and other Ramp Creek formation sites yield the finest preserved crinoids in the world.

Springer states in "THE CRINOIDEA FLEXIBILEA",

> "Next to Burlington the most famous crinoid locality in America is Crawfordsville, Indiana containing the largest colony of Paleozoic crinoids ever found, specimens are to be seen in all Museums. The number of species does not exceed 40 but the specimen occur in great profussion, and at certain spots in excellent preservation as to arms and stems, but not as to fine structures.
>
> A still more important locality, if not so famous, in the same area but slightly lower (is now considered to be higher or younger) was on Indian Creek about 12 miles from Crawfordsville. It was discovered by Mr. Beachler while collecting for me in 1888, being a small colony which produced several thousand specimens of about 20 species in a state of preservation nowhere surpassed especially to structural details".

Beachler's Great Nest has been exploited by the modern-day commercial collector with very little or no crinoid material left.

PALEONTOLOGY AND PALEOECOLOGY

The Borden Group is considered to contain the Edwardsville Formation and Ramp Creek Formation (Indian Creek crinoids) and is chiefly composed of siltstone and limestone. siltstone is from silt which was deposited in a delta. The limestone for the most part contain disarticulated crinoid remains. This Borden Delta was fed by one or more rivers located northeast of Indiana. Various lobes formed across Indiana, Kentucky and Illinois. As crinoids grew in colonies or stands, from time to time there would be a large influx of sediments due to inland flooding or possibly geological disturbances and the crinoids would be covered with silt. In time this would cause their fossilization.

While the two areas, Indian Creek and Corey's Bluff have some similarities they also have differences. Any two spots in either area has its own differences. These may be population of species, densities , various species present or absent, or sedimentation variation.

The paleoecology and taphonomy (from time of death to discovery) can change quite drastically over two spots not far from one another in a vertical or horizontal direction.

The Crawfordsville fauna at Corey's Bluff is one of the most diverse Paleozoic faunas in North America according to Dr. Lane's work. Most phylum of Mississippian marine animals are represented by fossil remains at this spot. Fossils from soft bodied, "worms", trace fossils to shark teeth. But what drew collectors to the Bluff and still does today, are the fabulous crinoids in diversity of species in many sizes and shapes.

From my own studies the Indian Creek fauna has as great a diversity as the Crawfordsville area. Especially the crinoid fauna. I have collected over 50 species from one location and approximately 130 species from all the various locations.

The collecting is very interesting in the area. You find some of the advanced Paleozoic crinoids with some of the more primitive crinoids of the Paleozoic Period.

It is my belief after collecting and studying crinoids from Montgomery, County, that the two sites: Corey's Bluff and Indian Creek are both more contemporary than most might believe them to be. The Indian Creek crinoids are somewhat younger but I believe the great difference in the species is the composition of the crinoid beds due to environment more so than an evolutionary change over time. (Fig.1) Crinoids change morphologically quick over a short period of geological time. Because of this fact and the fact I have found over half of the Crawfordsville species in the Ramp Creek Formation of Indian Creek has led me to believe they are close to one another in age. Macrocrinus represented by four specimens from Corey's Bluff is the most common species at Indian Creek. The species most common at Corey's Bluff is Platycrinites hemisphericus. There are only two that I know of from Indian Creek, that is in a period of over 20 years collecting. The species Scytalocrinus robustus, is equally common at both locations (Fig.2)

The crinoids from Corey's Bluff are more robust for the most part. That is, a specific species of Taxocrinus from Corey's Bluff is larger in the adult stage than the adult of Indian Creek. Sometimes the Bluff's crowns are in various stages of geodization which causes the crown to expand and enlarge in the process. When this happens there is a seam which developes between the plates of the crown. Again differences are more likely environmental.

For over a century and a half, man has been fascinated by the crinoid from Montgomery County, Indiana for various reasons. In the last twenty years these crinoids have once again been exploited by the commercial collector just as they were 150 years ago.

As in the early days, crinoid collecting and selling was the chief motivation with little or no regard for the rich associated fauna found at these sites. These rich assemblages of fossils are being torn apart for the crinoid only, with valuable scientific information being trampled underfoot.

No one knows exactly what the future has in store for what is left of the Montgomery County sites, but one thing for certain is that accessibility and fossils of most of the locations are exhausted or will be in the near future.

CLASSIC MONTGOMERY CO., INDIANA CRINOID FAUNAS

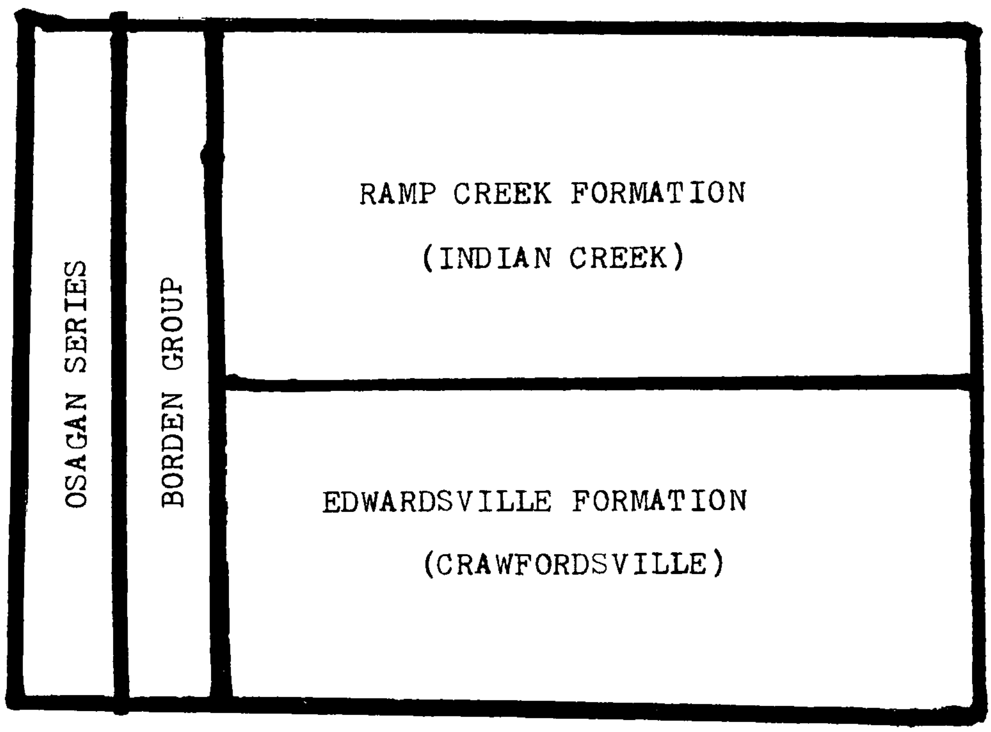


Figure 1 Mississippian Stratigraphy of Montgomery Co., Indiana Crinoid Faunas

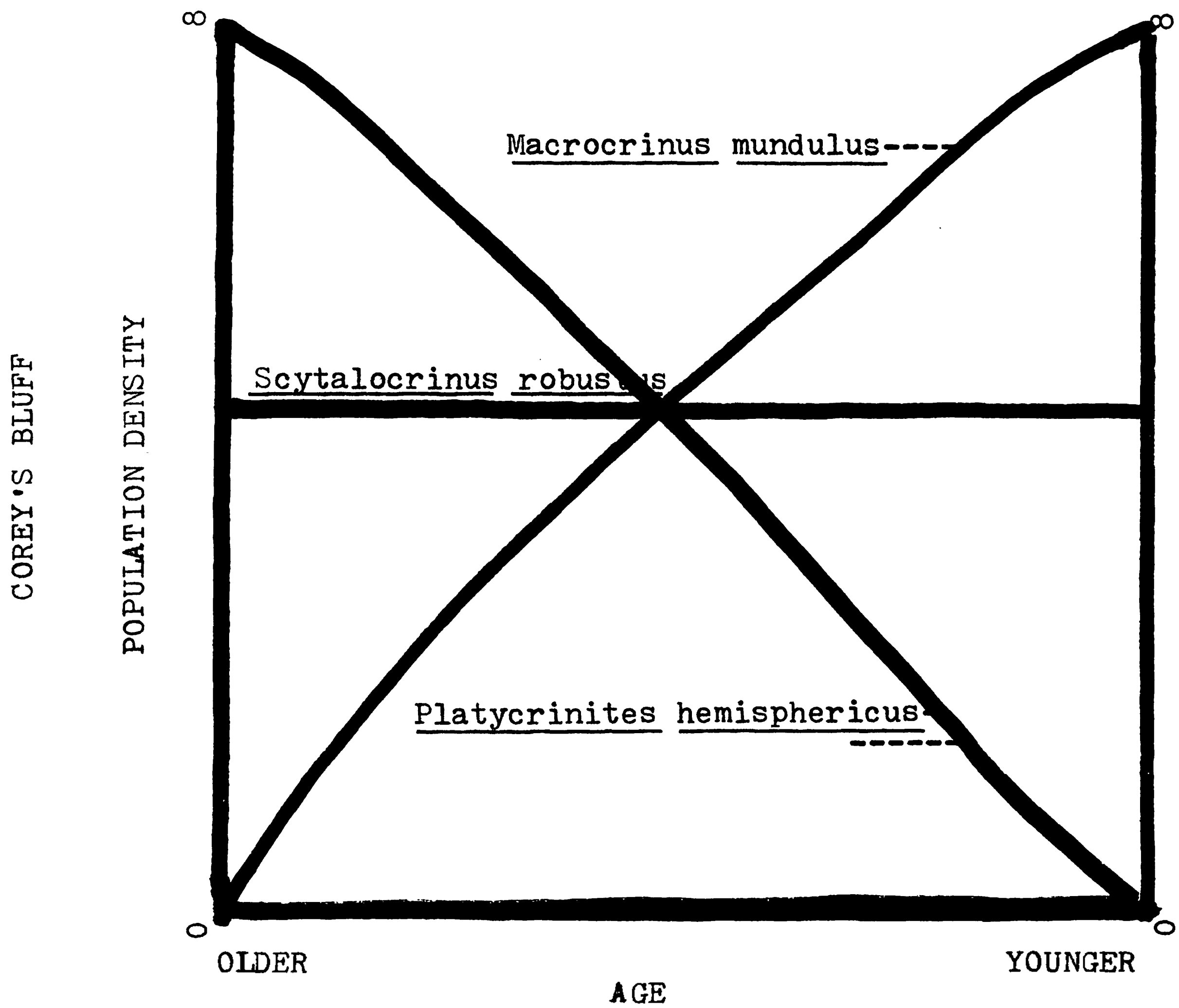
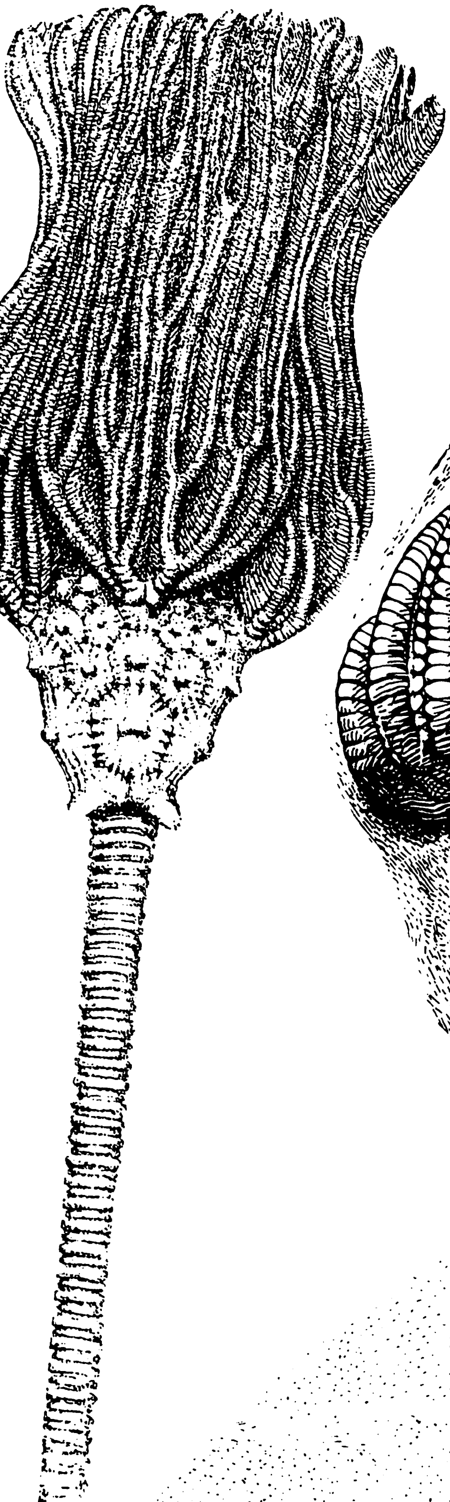
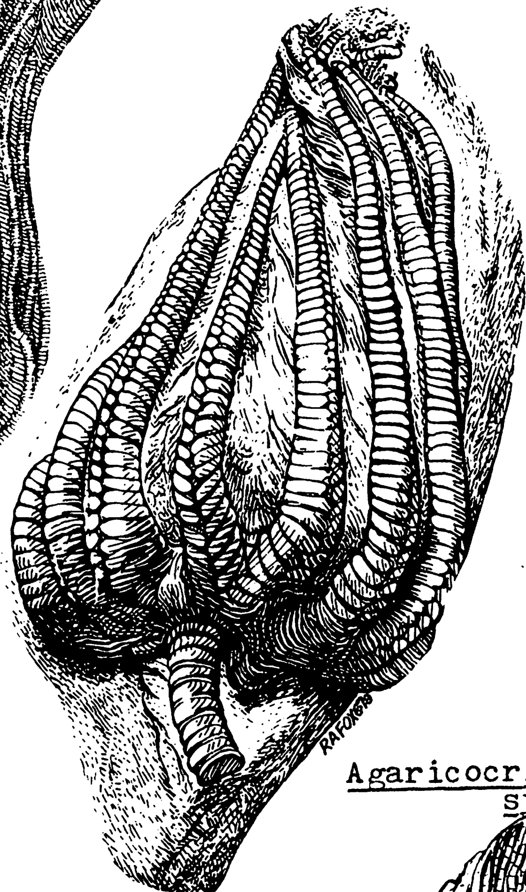


Figure 2 Comparison of Species Between
Corey's Bluff and Indian Creek

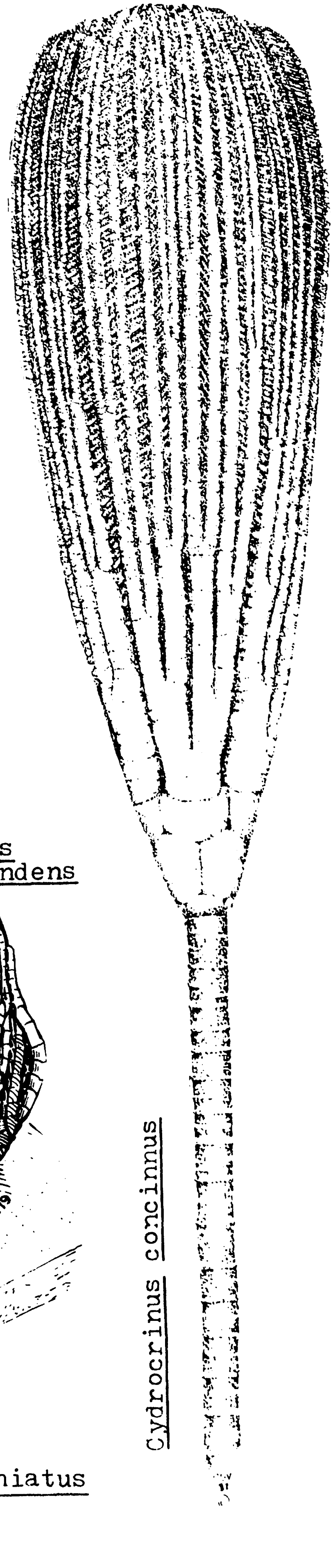
SOME CRINOIDS FROM MONTGOMERY COUNTY, INDIANA



Actinocrinites gibsoni



Agaricocrinus splendens



Cydrocrinus concinnus

Cyathocrinites multibrachiatus

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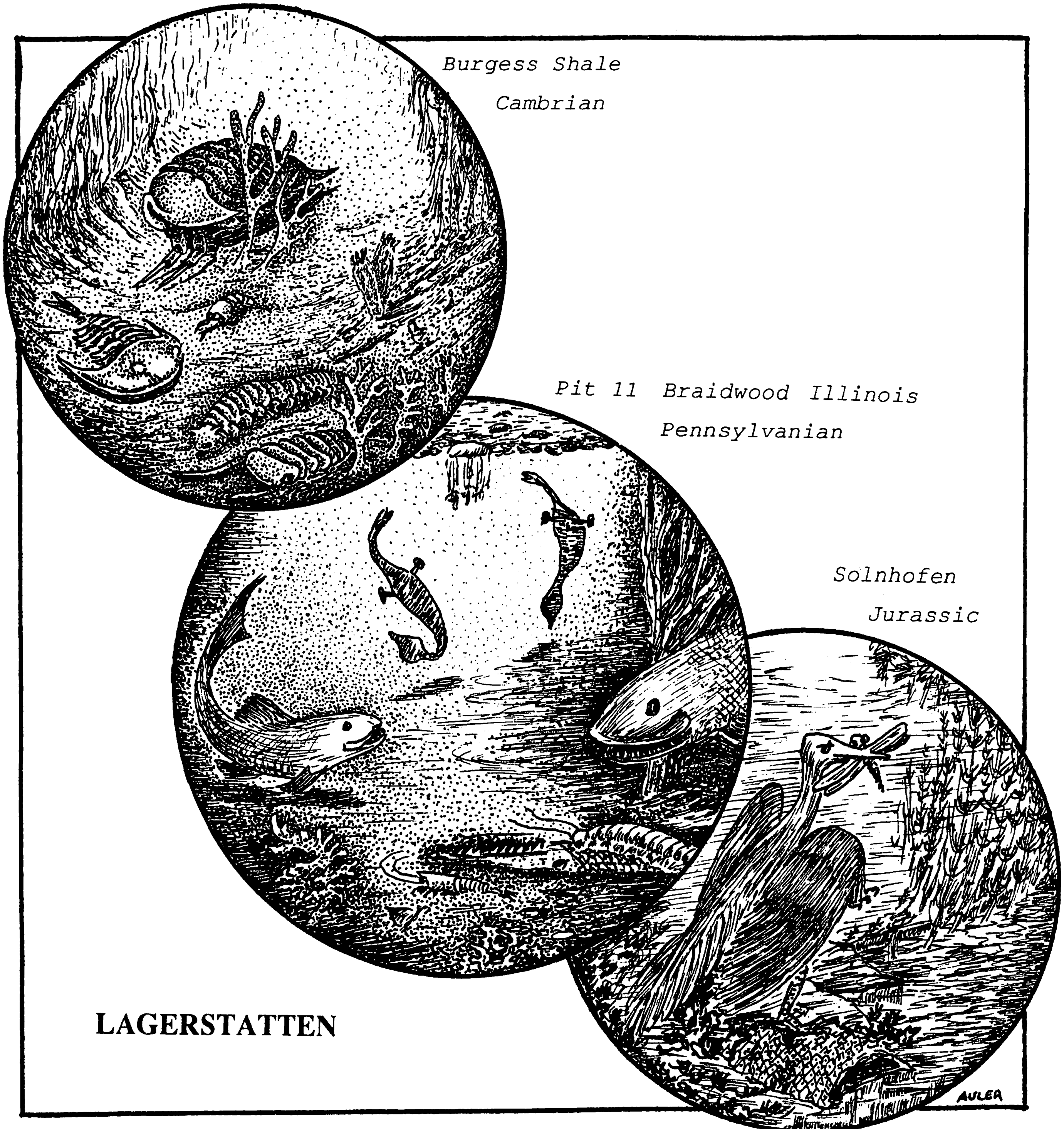
Line drawing by Scott Vergiels and R. A. Fox



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